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UNIVERSITY OF CALIFORNIA

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E. W. HILGARD, Director

PRESERVATION OF UNFERMENTED GRAPE-MUST

By F. T. Bioletti and A. M. dal Piaz

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PRESERVATION OF UNFERMENTEO GRAPE-MUST.

By FREDERIC T. BIOLETTI and A. M. DAL PIAZ.

The use of unfermented grape-juice or "must" as a beverage, both in health and sickness, has been common in vine-growing countries from time immemorial. It has, however, until lately been restricted to the immediate vicinity of the vineyards and the season of ripe grapes. This is owing to the great facility with which fruit juices of all kinds spoil within a few days after being expressed from the fruit, unless preserved artificially. The great progress made within the last few decades in methods, both legitimate and illegitimate, of food preservation, has made it possible to keep grape-juice for an indefinite period, and to make use of it as a beverage at all seasons and in all places. Accordingly the manufacture of grape-must has attained notable proportions in some European countries, and in some parts of the United States. Its use, however, has up to the present day been almost exclusively medicinal, although it is one of the most wholesome and agreeable beverages known, in health as well as disease. The cause of this restricted use is twofold. In the first place, in order to simplify and cheapen the processes of manufacture, injurious preservative agents have been made use of by the unscrupulous, and, in the second place, the lack of the necessary special knowledge and technical skill has resulted in many failures of attempts to preserve the must in a legitimate manner, so that the price has been necessarily too high for the regular consumer.

It is to remedy this lack of knowledge on the part of the manufacturer, to warn the consumer against the injurious effects of antiseptics, and to call attention to the merits of this delicious beverage, that this Bulletin is written. More stress is laid on general principles than on actual methods, as the methods will vary considerably according to the scale on which the manufacture is conducted and according to the facilities and appliances at the disposal of the individual manufacturer. The business can be conducted profitably with either small or large quantities, but must necessarily be commenced on a modest scale by the inexperienced. The directions given here should enable almost any grape-grower to commence operations, and gradually, as he acquires confidence and skill, to engage more largely in what should be an important industry in California.

Composition of Grape-Must.—A consideration of the following table, showing the constituents of the normal juice of ripe grapes, will make clear its value as a nourishing beverage in health, and also its therapeutic efficacy in certain cases of disease:

	Parts in 1,000.
Grape sugar (dextrose and levulose)	180 to 280
Free organic acids (tartaric, malic, tannic)	1 to 10
Salts of organic acids (cream of tartar, potassium malate, calcium tartrate, calcium malate	4 to 8
Ash (containing potassium, sodium, calcium, magnesium, ferric oxide, phosphoric and sulfuric acids)	3 to 5
Nitrogenous matter (proteids, amido-compounds)	3 to 10

This table shows that some of the principal constituents of wine, such as alcohol, glycerine, etc., are totally lacking in pure grape-juice; and it is to be noted that it contains no unwholesome substance of whatever kind.

Grape-juice should and can be delivered to the consumer so as to contain no other substances than those shown above. If chemical analysis shows any other ingredients, a fraud has been practiced; and as all the additions usually made are in the nature of antiseptics or preservatives, they are all more or less injurious. All the antiseptics used are easily detected by more or less simple chemical tests, and if an effective pure-food law were in operation it would be easy for the consumer and the honest producer to protect themselves by occasional chemical analyses of the various brands of grape-must on the market. In the larger European countries, where such laws do exist, the use of injurious adulterants is rendered dangerous, if not impossible.

An analysis of a pure grape-must made by a government chemist in Austria, and one of must put up by Swett & Son, at Martinez, made by Mr. G. E. Colby at this station, gave the following results:

Analyses of Grape-Must.

	Austria. Per Cent.	California. Per Cent.
Solid contents by spindle (Balling)	21.62	20.60
Alcohol	none	none
Total acid (as tartaric)	.78	.53
Volatile acid	.01	.03
Grape sugar	19.62	19.15
Cream of tartar	.61	.59
Free tartaric acid	.03	.07
Ash	.37	.19
Phosphoric acid	.02	.04

No cane sugar, starch sugar or antiseptics, were found in the California or the Austrian musts. Artificial (Anilin) coloring matter, salicylic, benzoic and boracic acids, formalin and fluorides were tested for in the California must but none were present.

This is approximately what should be shown by any pure grape-juice. It is instructive to compare this with some partial analyses, made at this station, of some of the beverages offered to the consumer in California under such titles as "Unfermented Wine," and "Pure Grape Juice," recommended for invalids and for communion purposes:

SAMPLE 1.

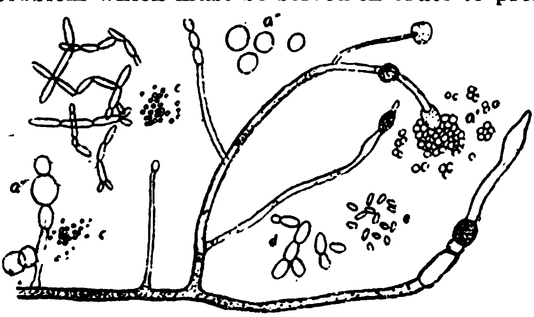
	Per Cent.
Solid contents by spindle	22.00
Total acids (as tartaric)	.59
Sulfurous acid (antiseptic)	.06

SAMPLE 2.

	Per Cent.
Solid contents by spindle	20.80
Alcohol, by volume	2.00
Salicylic acid (antiseptic)	3.90

The first sample was sold as a "curative for throat and lung troubles." The amount of sulfurous acid it contained was sufficient to *cause* throat and lung as well as digestive troubles in a healthy person. The second sample was sold as "pure unfermented grape-juice," but besides containing a large amount of the injurious antiseptic salicylic acid (more than twenty times as much as was necessary to preserve it), it contained two per cent. of alcohol. Even healthy persons, much more invalids, would contract severe indigestion from the use of such a product, which is a fraud upon the public.

Causes of spoiling.—In order to make clear the nature of the problem which must be solved in order to preserve grape-juice indefinitely, a short account of the causes of spoiling will be useful. When grapes, or any fruits, are gathered, the surfaces in contact with the air have the spores of various fungi, yeasts, and bacteria adhering to them. All these spores are microscopic, but an idea of their appearance, when sufficiently enlarged by the microscope to be visible, may be obtained by reference to Fig. 1, which shows various forms of these organisms developed on the skin of a muscat grape.



a, a', a''. Various forms of a mold, (*Mucor*).
c, d, e. Various forms of yeasts, molds, and bacteria.
Fig. 1.—MICRO-ORGANISMS ON GRAPES.

When the grapes are crushed and the juice expressed, the latter will be contaminated by these spores, washed off the skin. In the air they are dry, and therefore inert; but very soon after they are surrounded by the must, which is a very favorable medium for their growth, they assume an active form and commence to multiply. If the must is warm, this change to an active state occurs very soon and the consequent increase in numbers is proportionately rapid. If, on the contrary, the grapes and therefore the must be cool, the increase is much slower; but, eventually, if left alone the organisms increase until the must ferments. This fermentation consists principally in the changing of the grape sugar into alcohol and carbonic acid, and is the essential part of the process which changes grape-juice into wine.

The main object, then, of the producer who wishes to place "pure unfermented grape-juice" upon the market, is to permanently prevent this fermentation. Besides this, the grape-juice must be quite clear, in order to present an attractive appearance to the consumer.

To attain the first object there are two general groups of methods, which may be called respectively *chemical* and *physical*. All the chemical methods consist in the addition of germ poisons or antiseptics, which either kill the microscopic organisms of fermentation or permanently prevent their growth and increase. Of these substances the principal used are, besides salicylic and sulfurous acid already mentioned, boracic acid, saccharin, and, of late, formalin. Many patent preservatives are found on the market, but they nearly all contain one or more of these substances as their active principle. They are all injurious to digestion and in other ways; and it may be said in general that any substance which prevents fermentation will also interfere with digestion, and is therefore to be avoided.

The *Physical* methods work in one of two ways: they remove the germs by some mechanical means, such as a filter, or a centrifugal apparatus; or they destroy them by heat, cold, electricity, etc. The methods which depend upon the removal of the germs are inapplicable, as this cannot be done thoroughly except with very small quantities of liquid, and the minute organisms with which we have to deal will soon increase sufficiently to spoil the liquid, if a single one escapes the filter. One yeast-cell, for instance, at ordinary temperatures will increase to tens of millions in three or four days; and if the temperature is warm the increase will be still more rapid. We are, then, reduced to those physical methods which destroy the germs; and of these the only one which has been found useful in this connection is the use of high temperatures. This method depends on the fact that when a liquid is heated up to a sufficiently high temperature all organisms present are killed. This temperature is called the "death point," and differs for each particular variety of organisms. The death point will also differ according to the composition of the liquid in which the organism is immersed. Yeast, for instance, is killed at a lower temperature in must than in water, on account of the acidity of the former. Time, also, is a factor in determining the death point. An organism may not be killed if heated to a certain degree quickly and as quickly cooled; while if it is kept at that same degree for some time it will be killed. Some tests made at this station with a pure* yeast isolated from a California wine illustrate these facts. The yeast was placed in must which had previously been completely freed from all germs, and was heated to various temperatures for various lengths of time, with results as follows: The initial temperature of the must was 20° C. (68°F.) and the yeast was killed by heating it gradually up to 60° C. (140° F.) in fifteen minutes; that is to say, the time taken to bring the temperature from 20° C. (68°F.) to 60° C. (140° F.) was fifteen minutes, and at the end of this time the must containing the yeast was allowed to cool in a room at 20° (68° F.). This same yeast was not killed when heated in twenty-five minutes from 20° C. (68° F.) to 50° C. (122° F.), nor even when kept at the latter temperature for five minutes longer. But when kept at this temperature for ten minutes longer, all the yeast cells were killed. Another test with the same yeast showed that if heated from 20° C. (68° F.) to 45° C. (113° F.) in twenty minutes, and then kept at the latter temperature for twenty minutes, few or none of the yeast cells were killed, though in thirty minutes most of them were rendered incapable of growth. However, even in the last case some were left alive. and ultimately spoiled the must. We learn from these tests that heating to 45° C. (113° F.), even for a somewhat prolonged time, cannot be depended on to sterilize grape-must, and that even 50° C. (122° F.) requires too much time to be practical. A heating to 60° C. (140° F.), however, would probably be quite safe, provided that only this particular variety of yeast were present in the must. In practice, however, we have an unknown number of kinds of micro-organisms present, and some of them may be able to withstand a somewhat higher temperature than this.

It must be kept in mind also that fungi, including yeasts, exist in two states, the vegetative or growing state, and the spore or resting state. The latter is more resistant than the former; and it has been found that yeast spores, for instance, to be killed must be heated about 5° C. (9° F.) higher than the same yeast in the growing state. The above tests were made with yeast containing no spores; but, as in practice, spores may be and undoubtedly usually are present, a temperature 5° C. (9° F.) higher than indicated would be necessary. Practical experiments made at this station indicate that must can be safely sterilized at a temperature of 75° C. (167°F.) or 80° C. (176°F.) if all the precautions indicated below are observed. At this temperature the flavor of the grape-juice is hardly changed, though at between 90° C (194° F.) and 100° C. (212° F.) it is slightly affected.

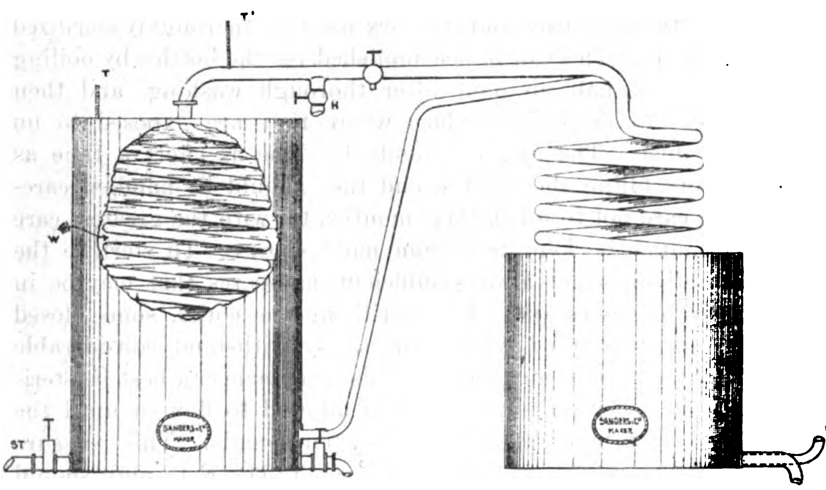
* Pure in this case means a yeast consisting of only one variety of micro-organism.

Another property of fungi and their spores, which is of importance in this connection, is their great resistance to heat when dry. Yeast can be heated in a dry state to a temperature above that of boiling water without being killed; the spores of some fungi (*e.g.*, common mold) are even more resistant. The bearing of this upon the preservation of must is that during the final sterilization, which takes place in glass bottles or similar vessels, portions of the inner surface of the cork and of the bottle above the liquid are comparatively dry; and if any spores should be adhering to these parts there is danger that they will not be killed, and that afterwards, when they come in contact with the must, they will grow and cause fermentation or mold. For this reason both the bottles and the cork must be thoroughly sterilized *before* being used. This can be accomplished for the bottles by boiling them for at least half an hour after thorough washing, and then allowing them to drain in a place where they are exposed to no draughts or dust. This boiling should be done as short a time as possible before filling the bottles, and they should be handled carefully, taking care not to touch their mouths, for with the greatest care the hands cannot be kept free from mold spores. To sterilize the corks this method is not always sufficient, as spores that may be in cracks are liable to escape. For sterilizing the corks, some closed receptacle should be used which will safely withstand considerable pressure. The corks when placed in this receptacle can best be sterilized by steam under pressure, which is allowed to flow in until the pressure, as shown by a gauge, is at least ten pounds. This pressure indicates a temperature of about 115° C. (239° F.), and should continue for at least twenty minutes.

Apparatus required.—The apparatus necessary for preserving grape-must on any but the very smallest scale consists of: 1, a continuous pasteurizer; 2, a pressure filter; 3, a pressure sterilizer for corks (this may be dispensed with); 4, a bottle pasteurizer; 5, a boiler for pressure steam. Certain other utensils are, of course, necessary, but they are such as are found in almost every wine-cellar.

The manner of operating.—The method of proceeding is as follows: Sound, clean grapes, preferably those having high natural acidity, are picked carefully, while cool, into clean boxes. They should not be too ripe or the must will be too sweet and difficult to clear. They should be crushed as soon as possible after picking, and the juice run into perfectly clean puncheons or other receptacles which have been previously steamed. If the must is cold—15° C. (59° F.) or under—it may be safely left to settle for twenty-four hours or more. This settling is an advantage, as it rids the juice of most of the floating solid matter, and facilitates the subsequent filtering. During this settling the must should be closely watched, in order to anticipate even a commencement of fermentation. After this settling, when the must has become almost clear, it is run through a continuous pasteurizer, of one form of which Fig. 2 gives an idea.

It is heated in this to 80° C. (175° F.) and should come out cool, not warmer than 25° C. (77° F.) and should pass into fresh settling receptacles. For this purpose puncheons or other casks may be used, if they have been thoroughly sterilized by steam, though the best receptacles would doubtless be casks or vats of metal lined with enamel, such as are now made. The greatest care must be taken to avoid contamination of the must as it flows from the pasteurizer. It



ST, Steam pipe. *H*, Outlet for hot pasteurized must. *U*, Inlet for unpasteurized must.
W, Water bath. *P*, Outlet for cooled pasteurized must. *T*, *T'*, Thermometers.

FIG. 2.—CONTINUOUS PASTEURIZER.

should pass directly, by means of a block-tin pipe, from the pasteurizer into the receiving casks. The end of this pipe should be thoroughly sterilized by plunging into boiling water, and should never be allowed to touch the hands or any exposed surface. When a receiving cask is full it should be closed immediately with a wooden bung, sterilized preferably in the way already described for corks. If all these operations have been conducted with the requisite care, and the casks kept in a cool cellar, the must will remain without fermenting for many days or even weeks. During this time it deposits more or less sediment which has been formed in heating. It is then ready for filtering.

Filtration.—This filtration is best accomplished by means of a filter so constructed that the must passes upward through the filtering medium, under pressure. Such a filter, made by the International Filter Co. of Chicago, is shown in Fig. 3.

This filter consists essentially of two shallow bowls clamped together mouth to mouth with the filtering medium between them. The unfiltered must enters the lower bowl through the pipe on the right of the figure, passes through the filtering medium into the upper bowl and makes its exit when clear through the faucet a little to the left of the middle of the figure. The small faucet at the bottom of the lower bowl is for the purpose of cleaning the filter. Occasionally, when filtration becomes slow, this faucet is opened for a few moments. This allows the sediment accumulated at the bottom to escape and at the same time the entering must takes a rotary course in the lower bowl, thus cleaning off the surface of the filtering medium; so that when the cleaning faucet is closed filtration proceeds as before. On a large scale, a filter press, such as is used in large wineries and in beet sugar factories, might conveniently be used.

It is impossible to prevent a certain amount of contamination by fungous spores during filtration; but it should be minimized as much as possible by the greatest cleanliness, and attention to sterilizing everything with which the must comes in contact. In this regard it should be kept constantly in mind that in an ordinary room or cellar, where there is little dust, there is comparatively little danger of contamination from the air, the main danger being from the solid surfaces with which the must comes in contact. The must may be bottled directly as it flows from the filter, or it may pass into a sterilized temporary receptacle, from which it is bottled. It should, however be placed in its final receptacles (bottles, etc.) the same day on which it is filtered, corked immediately, and sterilized as soon as possible, preferably within 24 hours.

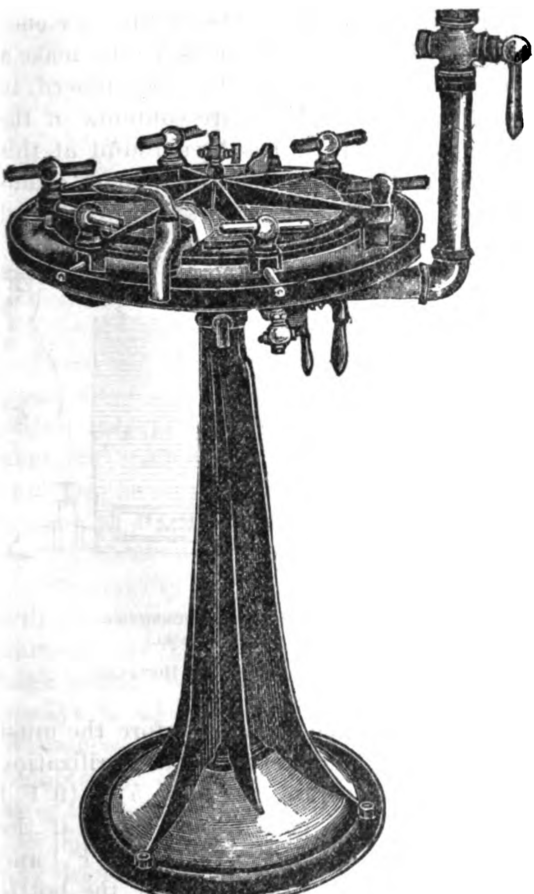
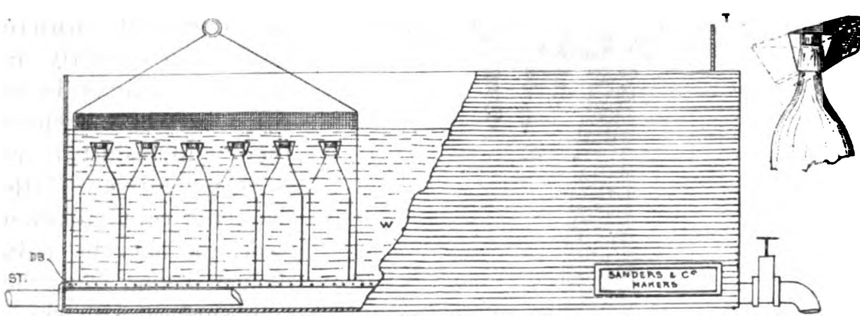


FIG. 3.—FILTER FOR CLARIFYING MUST.

Final sterilization.—On account of the recontamination during filtration, a final sterilization must be made after the bottles are corked. This is accomplished by means of a bottle-sterilizer, which the producer can construct himself. A simple and efficient form is shown in Fig. 4.

It consists of a wooden box or trough provided with a wooden grating placed about two inches from the bottom. The bottles, after being filled with the filtered must and corked, are placed in perforated, or wire baskets, which rest upon the grating. The trough should contain enough water to completely submerge the bottles. The water should be kept at a constant temperature of about 85°C.(185°F.) by means of a steam coil placed beneath the grating. The bottles should be left in this pasteurizer for exactly fifteen minutes if they are one-quart champagne bottles. For other sizes it is necessary to make a test with a bottle of must in which a thermometer has been placed, in order to determine how long it takes for the entire contents of the bottle to reach the required temperature. It has been found at this station, that although the must in the upper part of a quart champagne bottle reaches 75°C.(167°F.) in eight minutes, when surrounded



DB, Double bottom. *ST*, Steam pipe. *W*, Water bath. *T*, Thermometer.
(Bottle, shows method of adjusting a cork holder of sheet metal.)

FIG. 4.—CORK CLAMP AND PASTEURIZER FOR MUST IN BOTTLES.

by water at 85°C.(185°F.)it requires fifteen minutes before the must at the bottom of the bottle acquires that temperature. The sterilization in bottle should be conducted at a temperature at least 5°C. (9°F.) lower than that reached in the continuous pasteurizer. Thus, if the water in the first case was kept at 90°C.(194°F.) or 95°C.(203°F.) and the must attained a temperature of 80°C., the water in the bottle pasteurizer should be kept constantly at 85°C. and the time of pasteurizing so chosen that the must in the bottles will attain a maximum temperature of 75°C.(167°F.) *If the final heating is* *higher than the first, it may cause a precipitation of solid matters which will make the must cloudy in the bottles.*

During this sterilization in bottle the corks are liable to be expelled by the pressure developed. To prevent this they may be tied down with strong twine; but it is a great saving of time and labor to use some such contrivance as that illustrated in Fig. 4.

By this operation the must is thoroughly sterilized and will then keep unchanged for years, or until the bottles are opened. If, however, the bottles are to be capsuled, or kept in a very damp place, there is one other cause of spoiling that must be guarded against. However carefully all the various operations are conducted, there are sure to be mold spores on the upper surface of the cork. If this surface remains dry these spores will not grow, and are harmless. But when the cork is covered with a capsule the space between the capsule and the surface of the cork finally becomes moist, and any spores there will develop. Some molds have great penetrating power and may force their way either through the cork, or between the cork and the neck of the bottle (especially if the very best quality of corks has not been used) and finally reach the must. The molds which enter in this way do not, as a rule, grow into the liquid, on account of the small amount of air present; but they make a moldy layer on top, which lessens the selling value of the must, if it does not actually spoil it. This danger can be avoided by dipping the top of the neck of the bottle into a two per cent. solution of bluestone and water, in such a way as to wet the upper surface of the cork, before putting on the capsule. The same object may be attained by dipping the neck, in the same way, into very hot, melted paraffine. The bluestone acts by killing any spores that may be on the cork or which may find their way there later. The heated paraffine kills the spores present, and prevents later infection by completely covering the cork and keeping it dry.

The quality and character of the grape-juice prepared in this way will vary greatly according to the variety of grape used; and a pleasing variety may be obtained by using, partially or wholly, grapes of high aroma, such as Muscat, Isabella, etc. The color will, however, always be white or yellowish except with a few grapes, such as the Bouschets, which have pink or red juice. Red must, however, can be obtained by a modification of the process described. If the must, after it passes through the continuous pasteurizer, is allowed to come out hot and flow into a vat containing the skins of red grapes, almost any desired depth of color may be obtained, depending on the variety of grape used and the time during which the hot must is left in contact with the skins. Must prepared in this way, however, differs in other respects than in color from the white must. Besides coloring matter various substances are extracted from the skins, the principal being tannin. This makes the composition of the red must more like that of red wine, though of course it still contains no alcohol. A grape-juice of this character might appropriately be called "Unfermented Wine," and would doubtless be useful in medicine, as it would possess certain tonic properties not found in the white must. The regular consumer, however, would in all probability generally prefer the white must.

Grape-must, containing as it does generally from twenty to twenty-four per cent. of sugar, is too sweet for many palates and constitutions, but it may be diluted with water by the consumer to any desired extent; and a mixture of equal parts of grape-must and carbonated or mineral water makes a beverage much appreciated by many people. In Europe a certain amount of sparkling grape-juice is put up, *i.e.* grape-juice which has been carbonated, or charged with carbonic acid gas. This, though an addition to the natural juice of the grape, cannot be looked upon in any sense as a fraud or adulteration, and makes the beverage more palatable to many; besides if properly done it has no injurious effects on the health of the consumer.

In conclusion the following brief summary of the main precautions to be observed in the manufacture of unfermented grape-must may be useful:

1. Only clean and perfectly sound grapes should be used.

2. The grapes should be picked and handled when cool.

3. The greatest cleanliness is necessary in every stage of the process.

4. All utensils and apparatus used should be cleaned and sterilized immediately before using, and as short a time as possible after using.

5. The last sterilization should be at a temperature at least 5°C. (9°F.) lower than the temperature used in the first sterilization.

6. Reliable thermometers should be used, and the temperature watched very carefully.

UNIVERSITY OF CALIFORNIA—COLLEGE OF AGRICULTURE.
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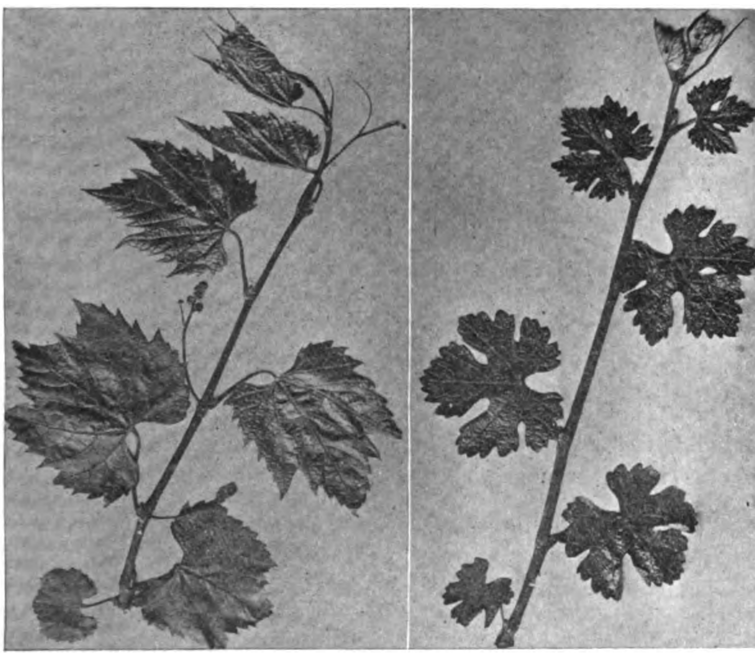
E. W. HILGARD, Director.

THE PHYLLOXERA OF THE VINE.

By FREDERIC T. BIOLETTI.



VITIS VULPINA (Riparia),
Typical wild vine from North America.
(Resistant.)

VITIS VINIFERA,
Wild vine from the Caucasus.
(Non-resistant.)

BULLETIN No. 131.

(Berkeley, May, 1901.)

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1901.

AVAILABLE PUBLICATIONS ON VINE AND OLIVE GROWING.

The following publications will be sent free on application:

Resistant Vines: Appendix to Viticultural Report for 1896.

Bul. 116: The California Vine-Hopper.

Bul. 119: Vine Pruning.

Bul. 120: The Olive Knot.

Bul. 123: Olives—Cultivation, Oil-Making, Pickling, Varieties.

Bul. 127: Bench-Grafting Resistant Vines.

Bul. 129: Condition of Olive Culture in California.

Bul. 130: Preservation of Unfermented Grape-Must.

Viticultural Report for 1887–95. (Contains on page 454 a list of the publications of the State Board of Viticulture, which will be sent on receipt of necessary postage.)

Agricultural Report for 1895–96, 1896–97, containing:
California Olives.
Wine, Table, and Raisin Grapes at the substations.

Agricultural Report for 1897–98, containing:
Notes on the California Vine-Hopper.
Revision of Bulletin 119: Vine Pruning.

THE PHYLLOXERA OF THE VINE.

The late discovery of the phylloxera of the vine in several important grape-growing districts which have hitherto been regarded as exempt has awakened widespread interest, and even alarm, among both wine- and raisin-producers. In order to satisfy the demand for information regarding this serious enemy of the vine, to allay the alarm of those who exaggerate its menace to the industry, and at the same time to rouse up to prompt and intelligent action those who are inclined to minimize the danger, the following brief account is issued.

Historical.—The phylloxera is a native of the United States east of the Rocky Mountains, where it is found living upon the wild vines. It is a minute insect related to the scale insects and plant lice. It was introduced into the south of France before 1863, upon rooted vines sent from America; though the insect itself was not found and described there until 1868. The infection commenced at two points: one in the southeast in Gard, the other in the southwest near Bordeaux. In 1868, when the nature of the pest was understood, it had already invaded considerable areas. The two areas first attacked gradually enlarged until they touched about the year 1880, and the insect began to spread northward. By 1884 about 2,500,000 acres, more than one third of all the vineyards of France, had been destroyed and nearly all the rest were more or less affected. The progress of the disease in parts of southern France was so rapid that in some towns vine stumps became the principal fuel. Since 1884 the pest has continued to spread with somewhat less rapidity in France, partly because the most densely planted vineyard districts had already been devastated, but also because elsewhere its progress was retarded by quarantine and other restrictive measures. No remedies yet discovered, however, are capable of exterminating the pest; and to-day there is no vine-growing region of any importance in France, or elsewhere, exempt from phylloxera.

The insect was probably introduced into California upon vines—cuttings or roots—imported from France, though it was possibly introduced from several sources and at several points. It was first noticed in the southern part of Sonoma County in the valley surrounding the old town of Sonoma, about 1874. By 1880 vines killed by the insect had been found in Napa, Solano, and Placer counties, and hundreds of acres had been pulled up in Sonoma Valley. Since then the insect has spread to all the important grape-growing regions of California north of Tehachapi,* and probably not less than 30,000 acres have been destroyed.

The Insect.—The phylloxera occurs normally in four forms, which have been called by Victor Mayet:

1. The gall insect, or form of multiplication;
2. The root insect, or form of devastation;
3. The winged insect, or form of colonization;
4. The sexual insect, or form of regeneration.

The gall insect lives upon the leaves, and is the commonest form on the wild vines in the native habitat of the insect. It rarely occurs in California. In Europe it is found often upon American and rarely upon European varieties. It causes little swellings or galls upon the leaves and younger parts of the vine, which, though sometimes very numerous, do little permanent injury. The chief danger from the gall form is that it multiplies with astonishing rapidity and migrates from the leaves to the soil. Here it attacks the roots and gives rise to the root form, which is the "form of devastation," the one which finally destroys all the vines it attacks which are "non-resistant." Every insect of the root form which reaches maturity lays about twenty-five or thirty eggs, each of which is capable of developing into a new egg-layer *needing no fertilization.* As there are from five to seven such generations during the year, the increase in numbers is extremely rapid.

Sometimes during the summer, usually in July or August, some of the eggs laid by the root insects develop into insects of slightly different form, called nymphs. They are somewhat larger than the normal root form and show slight protuberances on the sides, which finally develop into wings. These are the winged or colonizing insects, which emerge from the soil and, though possessing very weak powers of flight, are capable of sailing a short distance, and if a wind is blowing may be taken many rods or even miles. Those which reach a vine crawl to the under side of a leaf and deposit from three to six eggs. These eggs are of two sizes, the smaller of which produce males and the larger females. The female, after fertilization, migrates to the rough bark of the two-year-old wood, where she deposits a single egg, called the winter egg, which remains upon the vine until the following spring. The insect which hatches from this egg in the spring goes either to the young leaves and becomes a gall-maker, or descends to the roots and gives rise to a new generation of egg-laying root-feeders. The normal and complete life

* The phylloxera is said to have been found once in Southern California; but as the vineyard was uprooted and destroyed the insect was probably extirpated.

cycle of the phylloxera appears then to be as follows: *Male* and *female insects* (1 generation in autumn); *gall insects* (1–5 generations while the vines are in leaf); *root insects* (an unknown number of generations throughout the year); *nymphs*, which become *winged insects* (1 generation in midsummer). The gall stage may be omitted, as it generally is in California, and the insects which hatch from the fertilized eggs laid by the female go directly to the root and produce offspring, which are indistinguishable from the root form produced in the normal cycle. For how many generations the root form can exist and reproduce without the invigoration supposed to come from the production of the sexual form is not known, but certainly for four years and probably for more. The gall form on American vines can be prevented by spraying the vines in winter with liquids to kill the winter eggs; but this treatment has no effect on the root forms, which in California hibernate abundantly in the soil.

All forms of the phylloxera are extremely minute, the root form being about one twenty-fifth of an inch long when it reaches the adult egg-laying stage, and little more than half this length when young and active. It is just large enough to be seen by the unaided eye in a good light when its appearance is known, and, by the help of a glass magnifying five diameters, its legs and antennæ are plainly visible. Its color is light greenish-yellow in summer, and somewhat darker in winter; so that when numerous the attacked roots appear as though dusted in spots with powdered mustard or cinnamon. The newly-hatched insect is fairly active, and at first moves about from place to place on the roots; but finally, when it reaches the egg-laying stage, inserts its sucking-tube into the root and remains fixed.

Nature of Injury.—The amount of nutriment taken from the vine by such minute insects, even when present in the immense numbers in which they sometimes occur, is not sufficient to account for the disastrous effect upon the plant. The death of the vine is due to the decay which sets in wherever the phylloxera has attacked the roots. Wherever a phylloxera inserts its sucking-tube a swelling is produced, composed of soft tissue which soon decays. When this swelling occurs at the end of a young rootlet, growth in length is stopped; when it occurs on the larger roots, a kind of "cancer" or decay spot is finally formed, which soon extends around the root, and all below the point of attack dies.

During the first year or two after a vine is attacked there is little apparent damage. In fact, the effect of the phylloxera is equivalent to root-pruning, and in some cases results in an unusually large crop of grapes. The year after this crop, however, the vine having endured the double strain of heavy bearing and root injury is unable to recuperate,

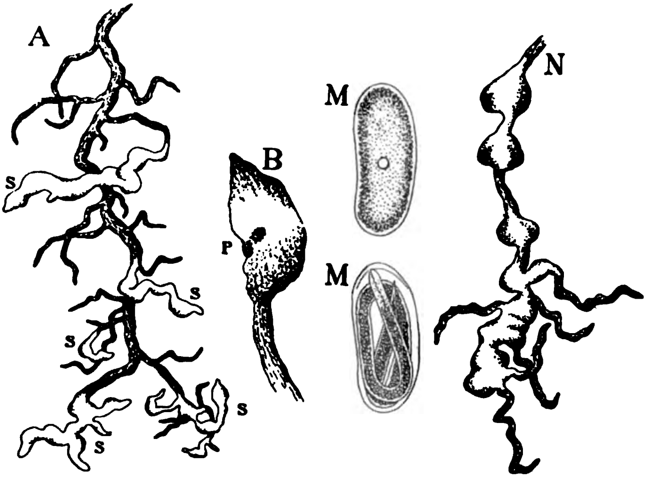

Fig. 1.   Fig. 2.

Fig. 1. Young roots of vine attacked by Phylloxera.
S—Nodosities or swellings caused by the insect.
B—One of these nodosities enlarged, showing position of the insects (P) and one-sided character of the swelling.

Fig. 2. Galls or swellings caused by Nematode worms, which occasionally occur on vine roots in wet soils. Note their symmetrical axial character, which distinguishes them from Phylloxera nodosities.
M—Eggs of the nematodes found in these galls.

and generally dies. In rich, moist soil the death of the vine is not so sudden, and two or even three small crops may be obtained after symptoms of the disease are evident.

Methods of Dispersal.—The ways in which new vines and vineyards become infested may be classed as natural and artificial. The natural ways may be inferred from what has been said of the life history of the insect. From a vine first attacked the root form spreads through the soil to neighboring vines slowly, but continuously, thus forming the so-called "oil-spots." A typical oil-spot of several years' standing will show several dead vines in the center, then a ring of vines with very short growth and no grapes, next another ring where the growth is not of normal vigor, but where the crop may be equal to or larger than that of the healthy vines. Such a spot enlarges its area year after year at a gradually accelerating rate as the front of the invading army becomes longer. The rate of advance will vary with the soil and climate, but will probably never exceed forty or fifty feet annually. If this were its only method of spreading, the insect could be controlled or even exterminated with comparative ease. Unfortunately, it is able to spread much more rapidly by means of the winged form; and the rapidity of its extension over the south of France was due principally to this agency. In California, though the winged form has been found, it seems to be rare, which probably accounts to some extent for the comparative slowness with which new districts have become infested. The artificial methods of dispersal are here probably more effectual in spreading the insect than the natural. The insects are taken from one part of the vineyard to another on pieces of the roots of infested vines, adhering to the plows or other implements used in cultivation; while they are introduced into new localities on rooted vines or cuttings brought from infested districts.

METHODS OF COMBATING THE PEST.

The methods to be used in resisting this foe of the vineyardist may be divided into groups corresponding to different stages of infection and to varying local conditions. There are three cases to be distinguished, viz:

1. The district is uninfested;
2. A few small infested spots are known in the district;
3. The district is badly infested; i. e., shows many and widely distributed infested spots, even though none of the spots is large.

1. In the first case, all efforts should be directed to keeping out the pest, and the only effectual means is a rigidly enforced embargo on all material capable of introducing it. Wherever the vineyard interest is of sufficient importance this should extend to the exclusion from infested districts, not only of all vine roots and cuttings, but also of all other plants, such as nursery stock, potatoes, etc., which are taken from below the ground. Although the phylloxera, so far as known, feeds on nothing but the vine, there is always danger of eggs or insects being contained in the earth attached to any kind of root. This measure, consistently carried out, has kept the province of Algiers free from infection, though the neighboring province of Constantine has been a prey to the pest for many years.

2. In the second case, where the insect has already obtained a foothold, the first step to take is to determine as nearly as possible the exact extent of the infested area. If it is found to be confined to a small, isolated vineyard, an effort should be made to completely eradicate the pest. This can be done only by destroying the vineyard, by subjecting it to what is called the "death treatment." This is best done (after grubbing up the vines and burning them on the ground) by making an embankment around the whole vineyard and then running water on to it until it is converted into a lake. The water should be kept continuously at a depth of at least six inches until all the insects are destroyed. The best time to do this is in May or June, as at that time four weeks' continuous flooding is sufficient to kill both insects and roots. It is important that every root should be killed in order that, if any insect survives the flooding, it will die for lack of food. Where

flooding is impracticable, the vines should be grubbed out and burned in the same way, and the ground kept clean of all growth for at least one year. This is in order that any suckers which may come up from the roots may be destroyed immediately. If crops, or even weeds, are allowed to grow, some of these suckers may escape observation and serve to keep the insects alive to spread the pest the next year. If the affected spot is not too large it is well to disinfect the soil with bisulfid of carbon. This is applied by pouring one ounce each into holes placed two feet apart all over the land to be treated. These holes should be about one foot deep and can be made with a small crowbar or dibble. After pouring in the liquid, the hole should be closed by pressing earth into it with the foot.

If, however, the pest has obtained a foothold in several vineyards of the district, or in a large vineyard, it is practically hopeless to attempt to eradicate it. In this case all we can reasonably hope to do is to delay the spread of the pest as much as possible and in the meantime to place all new vineyards on a permanently phylloxera-resistant basis. Every infested spot in the district should be diligently sought out and treated. The treatment consists in digging up and burning every vine in each spot which shows symptoms of attack, together with at least three rows of apparently healthy vines surrounding them. Disinfection of the soil of these spots by flooding or with bisulfid of carbon is then advisable wherever practicable, but in any case these spots should be strictly isolated in all farming operations. In cultivating the healthy parts of the vineyard, to pass through the infested spots with plows or hoes is a most effective method of accelerating the spread of the insect. The search for infested spots is most easily and thoroughly done in July or August, as at that time the shortness of growth in the "oil-spots" is most readily detected and the insects are easily found, as they are in large numbers on the surface roots and generally also on the trunk of the vine just below the surface of the soil. The search for and destruction of infested spots should be repeated every year; and if commenced in the early stages of infection and prosecuted with sufficient thoroughness in every vineyard throughout a district, will effectually prolong the life of the bulk of the vines for many years. As soon as the actual presence of the phylloxera in a district is known and all hopes of permanently eradicating it are abandoned, the embargo should be modified to the extent of admitting vine *cuttings*. These should be introduced, however, under strict quarantine regulations, including disinfection by responsible and properly instructed persons. Rooted vines, or cuttings with pieces of old wood attached, should still be kept out, as they cannot be disinfected with any certainty.

3. However conscientiously and completely these measures are enforced, a time will arrive sooner or later when the cost of inspection

and eradication will be greater than any benefit to be derived from them. We are then face to face with the third set of conditions; we must accept the phylloxera as a permanent inhabitant of the district and simply consider the best method of growing our vines in spite of its presence. By this time all embargo or quarantine regulations are useless and should be repealed.

Of the many thousands of methods proposed and tested for maintaining a vineyard in spite of the phylloxera but very few have been of the slightest practical value and only four are at present used to any important extent. These methods are:

1. Injection of carbon bisulfid;
2. Flooding or submersion;
3. Planting in sand;
4. Planting resistant vines.

The first two methods aim at destroying the insect; the last two, at rendering the vines immune to their attack. As neither of the insecticidal methods can be applied with sufficient thoroughness to completely eradicate the pest without also killing the vines, the treatments have to be repeated every year in order to destroy the offspring of the few insects which escape the treatment of the previous year. For this reason these methods are being abandoned everywhere, especially in all new plantings, in favor of the others, which after the vineyard is properly started involve no further expense; and as planting in sand is of very limited and local applicability, it may be said that at present the only method that need concern grape-growers in California very seriously is the use of resistant vines. This tendency to resort to resistant vines to the exclusion of all other methods is well illustrated by the following statistics of the vineyards of Herault, one of the chief grape-growing districts of France, and that in which the conditions most resemble those of California:

	Acres of Vines.		
	1880.	1890.	1899.
1. Treated with carbon bisulfid	6,600	6,200	800
2. Submerged	3,900	15,000	11,000
3. Planted in sand	....	9,900	1,200
4. Resistant vines	6,600	311,000	440,000

Bisulfid of carbon is a liquid which volatilizes very rapidly at ordinary temperatures and gives off a poisonous and highly inflammable vapor. This vapor is heavier than air and therefore gradually replaces and saturates the air in the interstices of the soil when the liquid is injected. It is used at the rate of from 125 to 250 pounds per acre, and may be applied at any time except during blossoming and the ripening of the fruit. Two treatments, one directly after the vintage and the other a week or so before blossoming, give the best results. The liquid is applied by pouring from ¼ to ¾ ounce into holes made from 18 inches to 2 feet apart all over the vineyard, care being taken not to put any nearer than 1 foot from a vine. The holes are made from 12 to 15 inches deep, and are closed immediately after pouring in the liquid by pressing the soil with the foot. The holes may be made with an iron rod or dibble; but where the method is employed on a large scale special injectors are used, which much facilitate the work. The injections are best made when the soil is fairly firm, and when it is neither very wet nor very dry. This method succeeds only in rich, deep, loose soils, and cannot be used successfully in soil containing much clay, or on dry, rocky hillsides. It is most effective in sandy soils, where the nature of the soil is itself unfavorable to the insect. It is least successful in warmer locations, where the insect is most prolific and most harmful, and is used chiefly in the cooler locations where the phylloxera does least damage. Vines which are much weakened by the attacks of the insects cannot be successfully treated, and all treated vines require fertilization and most thorough cultivation. The annual cost for material alone would be from $15 to $25 per acre, at the present market price of carbon bisulfid.

Submersion is a cheaper and more effective method of controlling phylloxera, but is necessarily applicable to but few locations, and even where most successful is gradually giving way to the more satisfactory use of resistant vines. Its chief use is to preserve vineyards which are already in bearing, and it may be of use temporarily in some locations in California. During submersion the vineyard must be covered continuously with at least six inches of water, as the object is to drown the insects; that is, to kill them by depriving them of air. If the surface becomes exposed even for a brief interval air will be absorbed and the insects given a new lease of life. In very porous soils submersion is impracticable on account of the large amount of water required, and ineffective for the reason that the rapid passage of the water carries sufficient air into the soil to keep the insects alive. Submersion is most effective in destroying the insects when they are in their most active condition, that is, in summer. At this time, unfortunately, the vine is also most sensitive to injury. The most favorable time, then, for submersion is as soon as the vines have ceased active growth and before the phylloxera have entered their hibernating or dormant condition. This in most parts of California will be some time in October. At this period the flooding need last but a week or ten days; a month later, two or three weeks; while during the remainder of the winter little good results unless the submersion is prolonged for thirty-five or forty days, and indeed in some soils of the extreme south of France two months has been found necessary. As the insect is most susceptible in midsummer, it was at one time thought that a copious irrigation at that time sufficient to destroy most of the insects without injuring the vines could be effected. At present a flooding in July for not exceeding forty-eight hours is practiced in a few places, but only to supplement winter-flooding, or the injection of bisulfid. The insecticidal value of the short submersion which the vines will withstand at this time seems to be very slight. Its main value seems to be in promoting a vigorous growth of new rootlets to replace those that have been injured.

Planting in Sand.—Though no thoroughly satisfactory explanation has been given, the fact is established that in certain very sandy soils vines are uninjured by phylloxera. All sandy soils are unfavorable to the increase of the insect, and vines planted in them die more slowly than in others; but for complete immunity the soil must contain at least 60 per cent of siliceous sand. The looser and more fine-grained the sand, the more resistance it offers to the insect. Calcareous sands, those containing notable quantities of clay, all those in fact which have a tendency to form in lumps or "cake," offer less resistance.

RESISTANT VINES.

The most satisfactory method of combating phylloxera is the use of resistant vines, because it is applicable to all conditions and is the most economical in the end. A resistant vine is one which is capable of keeping alive and growing even when phylloxera are living upon its roots. Its resistance depends on two facts: *first*, that the insects do not increase so rapidly on its roots; and *second*, that the swellings of diseased tissue caused by the punctures of the insects do not extend deeper than the bark of the rootlets and are sloughed off every year, leaving the roots as healthy as before. The wild vines of the Mississippi States have evolved in company with the phylloxera, and it is naturally among these that we find the most resistant forms. No vine is thoroughly resistant in the sense that phylloxera will not attack it at all; but on the most resistant the damage is so slight as to be imperceptible. The European vine (*Vitis vinifera*, L.)* is the most susceptible of all, and all the grapes cultivated in California, with a few unimportant exceptions, belong to this species. Between these two extremes we find all degrees of resistance, which is expressed by a series of numbers ranging from 20, indicating the highest possible resistance, to 0, indicating the utmost susceptibility. The following table shows the resistance (accord-

*See frontispiece.

ing to Viala and Ravaz and other authorities) of some of the best known species and varieties:

COMPARATIVE RESISTANCE TO PHYLLOXERA.

Species (Wild Vines).		Cultivated Varieties and Hybrids.	
Vitis rotundifolia	19	Gloire de Montpellier (Riparia)	18
Vitis vulpina (riparia)	18	Riparia × Rupestris 3309	18
Vitis rupestris	18	Rupestris Martin	18
Vitis Berlandieri	17	Rupestris St. George	16
Vitis æstivalis	16	Riparia × Solonis 1616	16
Vitis labrusca	5	Solonis	14
Vitis Californica	4	Lenoir	12
Vitis vinifera	0	Isabella	5

The degree of resistance necessary for the production of good crops varies with the character of the soil. The resistance expressed by the numbers 16 to 20 is sufficient for all soils. A resistance of 14 or 15 is sufficient in sandy and moist, rich soils, where the vine can readily replace the rootlets as fast as they are destroyed. Fairly successful vineyards have been established exceptionally with vines having a resistance of less than 14, but as the vines become old the lack of resistance is generally shown by a weakening of the vine and a falling off of the crop. Many vineyards in the south of France grafted on Lenoir which formerly bore well, have now to be doctored with injections of bisulfid. For this reason it is advisable to reject all vines with a resistance of 13 or under, especially as vines with greater resistance can now be obtained for practically all conditions.

Resistant vines are of two kinds: (*a*) those which are grown for the grapes they produce, and (*b*) those which are useful only as stocks on which to graft the non-resistant varieties. The former are called "*direct producers*," the latter, "*resistant stocks*."

(a) *Direct Producers.*—When the phylloxera commenced to destroy the vineyards of Europe, the natural attempt was made to replace them with the varieties of vines which had proved successful in the United States, where the insect was endemic. These varieties, however, all proved unsatisfactory. Some, like the Concord and the Catawba, were insufficiently resistant, and although they could be grown where the severe cold of winter impeded the prolificness of the phylloxera, they quickly succumbed in the milder grape-growing sections of Europe.* Most of them were poor bearers compared with the prolific European vines, and finally the character of their fruit differed so widely from what Europeans were accustomed to that there was little sale for the fruit, and the wine could compete with only the very poorest quality of

* In California, these and other Labrusca varieties and hybrids resist very little longer than Vinifera vines.

Vinifera wines, and brought a very inferior price. A few of the varieties introduced during that first period are still grown to a limited extent in France, chiefly the Othello and the Lenoir. They are being gradually abandoned, however, as their crops are unsatisfactory, and in many localities can be maintained only by the aid of injections of bisulfid. For some years the search for a suitable direct producer was almost abandoned by practical men, the use of resistant stocks having been so fully successful. Lately, however, renewed efforts have been made and several new direct producers are being advocated and planted to some extent. The merit of these new varieties, however, is chiefly their resistance to Peronospora and Black Rot. Phylloxera-resistance is considered of much less importance by their most ardent advocates, and indeed the advice is given to graft some of the best of these direct producers upon phylloxera-resistant stock. The main importance of these facts to California grape-growers is that they hold out hopes of permanent prosperity for the wine-making industry here, where, owing to the dryness of the climate, there is no likelihood of trouble from these serious fungous diseases of the grape, which threaten to make the growing of Vinifera varieties impossible in many parts of Europe.

(b) *Resistant Stocks.*—Though high resistance to phylloxera is essential in a grafting stock, there are other characteristics equally necessary. The Rotundifolia (Scuppernong) which has the highest resistance of any vine, is useless as a stock on account of the impossibility of grafting it with any Vinifera variety. This is due to a lack of *affinity*, which means a lack of similarity in structure and composition between the tissues of the stock and those of the scion. This lack, in extreme cases, results in an imperfect and temporary union, but when not excessive, only in a slight decrease of vigor. The affinity is not perfect between Vinifera varieties and any resistant stock, but in the case of Riparia and Rupestris is generally sufficient to insure permanence to the union, and the slight decrease of vigor consequent often results in an increase of fruitfulness. It is for this reason that certain varieties when grafted on resistant stocks, especially on Riparia, often bear larger crops than when grown on their own roots. Not all varieties of Vinifera have the same affinity for the same stock. For this reason it is desirable to be cautious about making new or untried grafting combinations on a large scale. Some varieties, such as Carignan, Petite Sirah, Clairette, and Cabernet Sauvignon, do excellently on all stocks; while others, such as Mondeuse and Gamay, do not make a very good union with any of the thoroughly resistant stocks. The Petit Bouschet and Cinsaut make very poor unions with any variety of Riparia, but do fairly well on Rupestris St. George. The Pinot Noir makes a vigorous growth upon Rupestris St. George, but bears much more prolifically upon Riparia Gloire; while the Mataro does not bear on Rupestris St. George and makes poor unions with Riparia Gloire.*

Selection.—A very serious defect of many resistant stocks is a slender habit of growth. This is true of most of the vines found growing wild, and cuttings from such vines make poor grafting stock for the stout Vinifera varieties, which will produce a trunk four inches in diameter while the stock is growing only two inches. This is particularly true of the wild Riparias. For this reason great care has been exercised in selecting the stronger-growing forms, and at present we have selected Riparia-varieties which almost equal Vinifera in the stoutness of their trunks. The best of these are the Riparia Gloire de Montpellier and the Riparia Grande Glâbre, the first of which has given the best results in California.

Adaptation.—The European vine is remarkable among cultivated plants for the wide range of soils in which it will succeed. We find vineyards producing satisfactory crops on the lightest sands and on the heaviest clays, on the dry hill-tops and in the low, moist plains. This is not the case with resistant stocks. Some, such as the Rupestris varieties, are suited to the driest soils; others, like the Riparia varieties, grow well only on rich, moist soils. The question of the adaptation, then, of resistant stocks to various soils is of the greatest importance if we are to obtain the best results.

After rejecting all unselected and unnamed varieties, such as the ordinary Rupestris and Riparia, which have caused so much disappointment and loss on account of their poor growth, and all insufficiently resistant varieties, such as Lenoir, which have succeeded only in the richest soils, our choice of a resistant for a particular soil, climate, and scion must depend on its qualifications as regards *affinity* and *adaptation*.

After testing hundreds, if not thousands, of varieties and hybrids originated in Europe and America, a few have been selected as the best for practical purposes. In France a fairly good resistant stock has been found for nearly every soil. In California little systematic work has been done in this respect, and we still have the intricate problems of *adaptation* to solve for most localities. We can, however, profit to some extent by the experience of Europe, and some of the best varieties have been partially tested here and give great promise.

For the driest soils, on hillsides with a southern exposure, the Rupestris Martin is the most promising variety. Though not quite such a vigorous grower as the St. George it has greater resistance to phylloxera, and where grafted has given equal if not superior results. Where the soil is somewhat compact the Rupestris St. George is to be preferred, but neither of them should be planted where, on account of

*"Reconstitution du Vignoble," par P. Gervais, 1900.

an impervious subsoil or a high water-table, deep penetration of the roots is impossible.

For very shallow soils no resistant has been found that gives perfectly satisfactory results, but in such situations Riparia often does better than Rupestris. Where ground water is too near the surface Rupestris is liable to fungous root-rot. Near Mission San José there are vineyards on rolling hills where the soil consists of a layer, from 2 to 4 feet thick, of the heaviest black adobe underlaid by a sandy subsoil. Here Riparia has grown more vigorously and produced better crops than Rupestris. The subsoil, though easily penetrated by vine roots and favorable to their growth in normal seasons, loses its water, which is taken up by the more hygroscopic surface clay in dry years. In such conditions the deep-rooted Rupestris suffers, while the Riparias, with all their roots in the adobe, remain vigorous.

For loose, moist soils on northern slopes, and in those situations where a horizontal root development is desirable or permissible, the Riparia Gloire de Montpellier is extremely promising. It should be planted wherever Riparias of any kind have proved to do well, as in certain soils and locations in the San Francisco Bay region, and in the sub-irrigated soils of parts of the San Joaquin Valley. Other very promising resistants are certain hybrids of Rupestris and Riparia, which in many ways combine the merits of both species. Of these, Riparia × Rupestris 3309 and Riparia × Rupestris 101[14] have given the most favorable impression in California. They are strong, vigorous growers, with a greater range of adaptation than the pure species, and a resistance to phylloxera equal to that of Riparia Gloire.

DISINFECTION OF CUTTINGS.

The simplest and most effective method of treating cuttings suspected of being infected with phylloxera is to expose them to the fumes of bisulfid of carbon. The treatment with liquid insecticides is not nearly so reliable, as Professor Hilgard pointed out many years ago, on account of the difficulty of wetting the buds of many varieties, owing to their protective covering of woolly hairs. Some fear has been expressed that the poisonous fumes would injure the vitality of cuttings, but Professor Hilgard demonstrated in 1881 that Zinfandel cuttings kept for twelve hours in an atmosphere saturated with the fumes showed no signs of injury, and grew as well as untreated cuttings. Recent tests with resistant cuttings, Riparia and Rupestris, indicate that they can be treated with equal safety, for even after twenty-five hours' treatment they were not killed, though their slowness in starting and callusing indicated that they were injured. After five hours' treatment Rupestris St. George cuttings were uninjured and sent out roots and buds vigorously and rapidly. A large lot (about 4,000 cuttings) of Rupestris St. George, Rupestris × Riparia 3309, Riparia Gloire, and Solonis were exposed in a saturated atmosphere of carbon bisulfid for seven hours, and at the present time they are rooting and show no signs of injury. As Professor Hilgard's experiments in 1881 showed that one half hour exposure was sufficient to destroy the summer eggs of the insect, the time latitude is quite sufficient for safety, even for the winter egg.

The method of using the bisulfid is as follows: Place the cuttings in a barrel, vat, or box made tight by means of a thick coat of paint, or of paper pasted on the inside. On top of the cuttings place a saucer or other shallow dish, into which to pour the bisulfid of carbon. An ordinary saucer will hold enough for a box 8 feet cube or a 200-gallon vat. For larger receptacles it is better to use two or more saucers. Deeper vessels will not do, as the saturation is not sufficiently rapid. After pouring the bisulfid into the saucer, cover the box with an oiled canvas sheet or other tight-fitting cover, and allow to stand for from forty-five to ninety minutes. At the end of this time there should be a little of the bisulfid left. If it has all evaporated this is proof that insufficient was used. No flame lights should be used, as the liquid burns easily and the fumes form an explosive mixture with the air. Care should be taken not to spill any of the liquid on the cuttings, as it may kill them. It is advisable to cut off about half an inch of the lower end of the treated cuttings before planting, as the vapor injures the open pith.

Besides disinfecting the cuttings in this way, all the packing material in which they come should be burnt, or if valuable, dipped in boiling water. Practically it is impossible to disinfect rooted cuttings satisfactorily on account of the difficulty of killing all the phylloxera without seriously injuring the vine roots.

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UNIVERSITY OF CALIFORNIA—COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

E. W. HILGARD, Director

FEEDING OF FARM ANIMALS

BY

M. E. JAFFA and LEROY ANDERSON

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AGRICULTURAL EXPERIMENT STATION

FEEDING OF FARM ANIMALS.

PRINCIPLES OF ANIMAL NUTRITION: COMPOSITION AND DIGESTIBILITY OF FOODS: COMMENTS ON VARIOUS FODDERS AND FEEDSTUFFS, INCLUDING SUGAR-BEET PULP: TABLES FOR COMPOUNDING RATIONS: SUGGESTIVE RATIONS FOR DIFFERENT FARM ANIMALS: USE OF FRUITS FOR STOCK.

The great interest which is being taken in the feeding of animals and the constant demands which are being made on this Station for information along these lines, has made it imperative for us to issue this Bulletin, setting forth the general principles underlying all animal feeding, together with such data and comments as have seemed most essential for the farmer and stockman. Notwithstanding that the majority of the experiment stations have issued bulletins covering the same subject, the climatic conditions obtaining in California and the wide difference in our foods from those of the older States render it necessary that this Bulletin be issued to deal more intelligently with the environments peculiar to this State.

Some of the matter here presented concerning the general principles of feeding is reprinted from the Annual Report for 1894–95, the edition of which is exhausted. So far as possible all analyses given are from our own laboratories, and represent foods grown in California. We have not been able, however, to analyze all the foods used in the State, and therefore have copied many analyses from Professor Henry's "Feeds and Feeding," in order to present the data in a more complete form.

OBJECTS OF FEEDING.

It is well known that the young animal body requires food to supply the material necessary for its growth. But beyond this, and continuing during and past the growing stage, there is a constant wearing out and breaking down of all the tissues of the body, and this loss must be supplied in order to keep the animal in a normal, healthy condition. Not only must the worn-out tissues be replaced, but the material used in producing the energy necessary for carrying on all voluntary and involuntary functions, must also be supplied. An animal which is working hard in the plow is using up a great deal of fatty tissue as well as muscle; but the animal which is doing nothing, that is, making no voluntary exertion, experiences a loss of tissue through the constant production of heat necessary for the maintenance of the normal body-temperature, and also for the performance of all the involuntary functions of the body. Hence, we might summarize the objects of feeding as follows:

(a) To maintain bodily heat.
(b) To repair waste of tissue.
(c) To reproduce young.
(d) To form new tissues or organs.
(e) To perform muscular labor.
(f) To secrete various products.
(g) To lay up reserve stores.

COMPOSITION OF FOODS.

In order to see how these objects may be best carried out, we must understand the composition of these tissues that need rebuilding, and also the composition of the various foodstuffs at our command. Viewing them side by side, for the purpose of better comparison, a general analysis shows each to consist of the same four main ingredients —water, mineral matters, nitrogenous and non-nitrogenous material.

Water constitutes about two-thirds of the weight of the body, entering into the composition of all its tissues and fluids. As it does not form nearly so large a proportion of the ordinary ration fed to stock, we can readily understand the necessity of its forming a separate part of the animal's food.

The *mineral matters* comprise about five per cent. of the body-weight, and have important functions to perform, such as entering into the formation of the teeth and bones, and regulating the density of the blood and other fluids of the body, such as the juice of the stomach, etc. When estimating food values the mineral or inorganic ingredients are generally omitted, not on account of any lack of importance of that portion of the food, but for the reason that nearly all feedstuffs, no matter of what description, contain a sufficient amount of these substances, which are mainly lime, potash, and phosphoric acid, with varying amounts of sodium, iron, magnesia, sulphuric and hydrochloric acids, silica, etc.

The *nitrogenous matters* of the body, of which the major part are called proteids, the only ones that contain nitrogen, are found mostly in the muscle, gelatinous part of the bones and tendons, brain, nerves, and internal organs; in short, all the working machinery of the body is composed principally of this important material. Similarly, in the foods, the main part of all the nitrogenous material is termed protein, signifying, by its Greek derivation, to take first place. Another name for the proteids is albuminoids. This important ingredient of the food is found largely in the white-of-egg, the "myosin" of lean meat, gluten of grains, oil-cake meals, etc. Besides the albuminoids there are other nitrogenous matters, chief among which is the class known as amides, which are found to a greater or less extent in all foods, more particularly in those of vegetable origin. The physiological action of amides is similar to that of fat and carbohydrates.

The albuminoids in the different food-materials are estimated from the nitrogen by multiplying the figure for the latter by 6.25; nitrogen being sixteen per cent. of the albuminoids. In England the factor used is 6.33.

The nitrogenous compounds of the food are generally, for the above reasons, reported as *crude protein*.

The necessity of the albuminoids, or protein, in the daily food of an animal depends not only upon its important relation to such tissues as bone, muscle, blood, nerves, tendons, etc., but also upon the fact that, as far as we know, no albuminoids or protein matter is formed in the body except by the transformation of similar substances presented to it from external sources. It cannot be obtained by conversion of any other material.

The protein can be changed into fats, and thus may serve as a fuel for the body, but *fats* cannot replace *protein*. Because the protein, or flesh-forming ingredients, *can* serve as fuel, and in certain cases take the place of fats and carbohydrates, it would be extremely unwise and uneconomical to use them for that purpose, as it would always be done at a far greater cost.

The *non-nitrogenous* part of the body is principally fat, the substance which is consumed in the production of heat and energy. The source of this element in foodstuffs is comprised in all those portions which are free from nitrogen. They are divided into two main classes —the *carbohydrates* and *fats*—and are identical with those found in the body, with the exception of starch and sugar, which are never found as such to any extent in the healthy body. The carbohydrates are sugar, gums, and woody fiber; the latter, in the statement of analyses of foods, is reported separately, while the remainder of the above are, in order to conform to the general usage, classed together under the head of "nitrogen-free extract." The gums play only a secondary part as regards the nutritive value of the food. The carbohydrates are first changed into fats, and then used as fuel; though it must be remembered that for the purpose of heat, fat is worth 2.25 times as much as carbohydrates (that is, 1 pound of fat is equivalent, when used as a fuel, to 2.25 pounds of starchy matter). When there is a deficiency in the amount of these elements in the food, the fat of the body is drawn upon.

The fat, as might be supposed, varies in amount more than any other substance of the animal body. The fat seldom falls below six, or rises above thirty per cent. If the supply is cut off, the surplus fat stored up in the body is drawn upon to keep the animal machinery going, and if this continues the protein is converted into fat and used as such. Thus, by having a proper proportion of fat in the food of the stock, not only is the fat of the body protected, but indirectly, also, the protein of the muscle and blood, which is most important.

The term fat includes the butter of milk, the fat of meats, oil of seeds, wax of plants, etc. It is determined by treating the perfectly dried substance with ether, the extract thus resulting being designated as "crude fat." As might be supposed, these ether extracts have different nutritive values—the fat from the green fodder being of less value than that from the meals and seeds. Some authorities, in estimating the nutritive effect of food, give to all the crude fats the same significance. The *use of fat* is mainly as a fuel supply to the animal body, although it may form fatty tissue, but *not muscle*.

In the following tables are given the analyses of the different foods which have been examined at this Station, and also those of some others, of practical interest to the feeders of this State, taken from Professor Henry's work on "Feeds and Feeding." Credit is due Messrs. Frank J. Snow and R. K. Bishop for assistance in the chemical work here reported.

TABLE I.—COMPOSITION OF FOODS.
Percentage Composition.

FEED STUFFS.	Water.	Ash.	Protein.	Fiber.	Starch, Sugar, etc.	Fat.
Green Fodder.						
Alfalfa	80.00	1.72	4.94	4.70	7.90	.74
Alfileria	80.00	1.72	2.83	4.72	9.81	.92
Australian saltbush	76.51	4.75	3.34	4.67	10.28	.45
Barley*	79.00	8.80	2.70	7.90	8.00	.60
Clover, red	70.80	2.10	4.40	8.10	13.50	1.10
Corn, Indian*	79.30	1.20	1.80	5.00	12.20	.50
Corn Kaffir*	76.13	1.75	3.22	6.16	11.96	.78
Cow pea*	83.60	1.70	2.40	4.80	7.10	.40
Flat pea	63.48	3.18	8.18	9.76	13.77	1.63
Horse bean *	84.20	1.20	2.80	4.90	6.50	.40
Hungarian grass*	71.10	1.70	3.10	9.20	14.20	.70
Marsh ("Briston") grass	50.00	2.83	5.14	12.76	27.72	1.55
Modiola decumbens	80.00	2.87	2.72	3.24	10.56	.61
Oats*	62.20	2.50	3.40	11.20	19.30	1.40
Orchard grass*	73.00	2.00	2.60	8.20	13.30	.90
Peas and oats	78.70	1.70	3.50	6.00	9.10	1.00
Rye*	76.60	1.80	2.60	11.60	6.80	.60
Sacalin, leaves	82.28	1.21	5.02	2.41	8.09	.99
Sacalin, stalks	82.09	.90	1.61	7.17	7.89	.34
Snail clover	81.25	2.07	2.85	4.66	8.41	.76
Soya bean*	75.10	2.60	4.00	6.70	10.60	1.00
Sorghum*	79.40	1.10	1.30	6.10	11.60	.50
Silage.						
Barley	74.00	2.49	2.56	8.96	10.76	1.23
Clover	72.00	2.60	4.20	8.40	11.60	1.20
Corn	75.36	1.57	2.10	6.39	13.78	.80
Oats	72.00	2.11	2.20	9.35	13.11	1.23
Orchard grass	77.00	2.00	1.87	9.12	8.64	1.37
Roots, Beet Pulp, etc.						
Artichokes*	79.50	1.00	2.60	.80	15.90	.20
Beet, mangels*	90.90	1.10	1.40	.90	5.50	.20
Beet, sugar	84.30	.90	1.80	.90	12.00	.10
Beet pulp, fresh	90.00	.36	1.15	2.11	6.25	.13
Beet pulp, silage	88.87	.45	1.50	3.55	5.40	.21
Beet molasses	25.70	8.80	7.30	....	58.20	....
Cabbage*	90.50	1.40	2.40	1.50	3.90	.40
Carrots*	88.60	1.00	1.10	1.30	7.60	.40
Olive pomace	17.30	1.75	7.61	42.67	13.11	17.56
Parsnips*	88.30	.70	1.60	1.00	10.20	.20
Pie melons	94.50	.40	.77	1.23	2.88	.22
Potatoes*	78.90	1.00	2.10	.60	17.30	.10
Pumpkins*	90.90	.50	1.30	1.70	5.20	.40
Sugar beet crowns	81.92	.81	1.91	1.91	13.38	.07
Sugar beet leaves	88.75	.67	1.91	1.42	7.22	.03
Sugar beet tops	87.14	.70	1.91	1.53	8.68	.04
Turnips*	90.50	.80	1.10	1.20	6.20	.20
Hay.						
Alfalfa	10.95	6.43	17.60	22.63	39.31	3.08
Australian saltbush	8.52	18.56	12.89	18.03	40.30	1.74
Barley, common	6.44	7.15	11.11	22.55	50.37	2.38
Barley, beardless	10.67	5.67	8.05	21.03	51.80	2.78
Clover, alsike*	9.70	8.30	12.80	25.60	40.70	2.90
Clover, bokhara	9.01	7.04	13.35	22.14	45.26	3.20

* From Henry: "Feeds and Feeding."

TABLE I.—COMPOSITION OF FOODS. (*Continued.*)
Percentage Composition.

FEED STUFFS.	Water.	Ash.	Protein.	Fiber.	Starch, Sugar, etc.	Fat.
Hay (*Continued*).						
Clover, bur	11.25	6.91	10.50	26.19	44.92	2.23
Clover, crimson*	9.60	8.60	15.20	27.20	36.60	2.80
Clover, red*	15.30	6.20	12.30	24.80	38.10	3.30
Clover, snail	10.15	9.92	13.65	22.34	40.29	3.65
Clover, white*	9.70	8.30	15.70	24.10	39.30	2.90
Clover, wild yellow	9.50	5.39	15.58	30.28	35.25	4.00
Cow pea*	10.70	7.50	16.60	20.10	42.20	2.20
Flat pea	10.00	7.83	20.16	24.05	33.94	4.02
Foxtail (*Hordeum jubatum*)	12.00	5.39	7.45	33.53	39.79	1.84
Hungarian grass*	7.70	6.00	7.50	27.70	49.00	2.10
Johnson grass*	10.20	6.10	7.20	28.50	45.90	2,10
Mixed cereal	7.65	5.91	7.30	24.80	51.59	2.75
Oat	10.09	7.00	7.44	24.80	48.22	2.45
Orchard grass*	9.90	6.00	8.10	32.40	41.00	2.60
Rye grass, perennial*	14.00	7.90	10.10	25.40	40.50	2.10
Soya bean*	11.30	7.20	15.40	22.30	38.60	5.20
Vetch*	11.30	7.90	17.00	25.40	36.10	2.30
Wheat	8.82	5.58	5.96	22.48	55.15	1.81
Wild hay, oat	10.00	5.59	5.70	37.19	39.25	2.28
Other Dry, Coarse Fodder.						
Alkali weed	13.40	9.25	12.30	17.30	44.25	3.50
Barley straw*	14.20	5.70	3.50	36.00	39.00	1.50
Corn fodder*	42.20	2.70	4.50	14.30	34.70	1.60
Gourd vines, "mock orange"	13.90	12.66	11.42	16.92	43.06	2.04
Lima bean straw	10.00	9.56	10.72	21.14	46.66	1.92
Oat straw*	9.20	5.10	4.00	37.00	42.40	2.30
Soya bean straw*	10.10	5.80	4.60	40.40	37.40	1.70
Wheat straw*	9.60	4.20	3.40	38.10	43.40	1.30
Grain and Other Seeds.						
Barley (rolled)	10.05	2.92	12.00	2.30	69.63	3.12
Broom corn	12.70	3.00	10.30	2.20	70.40	5.00
Bur clover seed	6.61	8.85	21.45	25.08	32.66	5.35
Corn, Indian*	10.60	1.50	10.30	2.20	70.40	5.00
Corn, Egyptian	12.63	1.92	9.96	1.93	69.70	3.86
Corn, Kaffir*	9.30	1.50	9.90	1.40	74.90	3.00
Cow pea*	14.80	3.20	20.80	4.10	55.70	1.40
Flaxseed*	9.20	4.30	22.60	7.10	23.20	33.70
Oats*	11.00	3.00	11.80	9.50	59.70	5.00
Rice	12.30	.30	8.40	....	78.60	.40
Rye*	11.60	1.90	10.60	1.70	72.50	1.70
Soya bean*	11.80	4.70	34.00	4.80	28.80	16.90
Sorghum*	12.80	2.10	9.10	2.60	69.80	3.60
Sunflower*	8.60	2.60	16.30	29.90	21.40	21.20
Wheat, plump	11.50	1.76	11.85	2.45	70.40	2.03
Wheat, shrunken	8.30	2.34	17.10	3.48	66.78	3.00
Mill and By-Products.						
Brewers' grains, dry*	8.20	3.60	19.90	11.00	51.70	5.60
Brewers' grains, wet	75.70	1.00	5.40	3.80	12.50	1.60
Cocoanut oil-cake meal	14.08	4.36	19.51	9.53	42.12	10.40
Corn meal	12.05	1.54	9.40	2.00	71.34	3.67
Cottonseed meal	9.85	4.86	47.25	3.19	22.64	12.21
Gluten feed*	7.80	1.10	24.00	5.30	51.20	10.60
Gluten meal*	8.20	.90	29.30	3.30	46.50	11.80

*From Henry: "Feeds and Feeding."

TABLE I.—COMPOSITION OF FOODS. (*Continued.*)

Percentage Composition.

FEED STUFFS.	Water.	Ash.	Protein.	Fiber.	Starch, Sugar, etc.	Fat.
Mill and By-Products (*Cont.*).						
Linseed oil-cake meal, N. P.	10.93	4.50	30.70	8.89	37.95	7.03
Linseed oil-cake meal, O. P.	9.35	5.22	29.75	6.23	31.20	18.25
Malt spouts	13.35	5.99	19.53	14.00	45.17	1.96
Mixed feed	10.57	3.57	12.00	9.66	59.98	4.21
Palm nut meal*	10.40	4.30	16.80	24.00	35.00	9.50
Pea meal*	10.50	2.60	20.20	14.40	51.10	1.20
Peanut meal*	10.70	4.90	47.60	5.10	23.70	8.00
Rice bran	10.55	6.64	14.96	4.85	50.20	12.80
Rice hulls	11.02	16.04	5.36	37.12	29.54	.92
Crushed barley	10.05	2.92	12.00	2.30	69.63	3.12
Rye bran*	10.60	3.60	14.70	3.50	63.80	2.80
Shorts	9.85	4.24	15.20	5.05	64.48	3.32
Wheat bran	11.67	5.18	14.05	8.16	57.34	3.60
Wheat middlings	11.73	2.85	15.22	4.88	60.85	4.47
Wheat screenings	11.67	2.94	10.06	5.48	67.63	2.72
†Miscellaneous.						
Blood meal	....	....	79.60	....	....	....
Distillery slops*	93.70	.20	1.90	.60	2.80	.90
Dried blood	8.50	....	84.40	....	....	2.50
Meat meal	7.50	....	42.90	....	....	....
Poultry food, Pratt's	14.63	6.19	13.52	5.35	55.91	4.40
Milk, whole	87.20	.70	3.60	....	4.90	3.70
Milk, colostrum	74.60	1.60	17.60	....	2.70	3.60
Skim milk, gravity	90.30	.70	3.30	....	5.30	.40
Skim milk, centrifugal	90.60	.70	3.30	....	5.30	.10
Buttermilk	90.30	.70	4.00	....	4.50	.50
Whey	93.40	.50	.80	....	5.00	.30

DIGESTIBILITY OF FOODS.

The chemical composition, alone, of the different food-materials is not of much value to the farmer or dairyman, if he does not know how much of each nutrient (the name given to the nutritive parts of the food—protein, fat, carbohydrates, and mineral matters) of the feeding-stuff in question is digestible, or available to the animal. Most of the experiments in this line have been made in Germany, although some of the Eastern States are now carrying on this kind of investigation.

In all foods there is always a certain portion of each nutrient, whether it be protein, fat, or carbohydrate, which is not digested or assimilated, but passes through the body, and is valuable only as manure. In order to ascertain how much of each food is not digested, the material is weighed and chemically analyzed before consumption, and the weight and composition of the animal excrement is also determined. The difference of the two analyses is taken as the quantity digested or assimilated. The results so obtained are termed *digestion coefficients*, and are only approximate, but, in the present

*From Henry: "Feeds and Feeding."

†The nutrients of the foods under this head may, for the purposes of this Bulletin, be considered as entirely digestible.

state of such researches, the best data available. For each food the digestion coefficient may vary considerably—the more concentrated the food, the higher, as a rule, will be the digestion coefficient. For instance, while about 57 per cent. of the protein is digestible in oat hay, 78 is the coefficient for grain middlings or bran, and in some of the peas and beans we find as much as 88 per cent. of this highly important ingredient to be digestible.

To illustrate the above statements: In every 100 pounds of alfalfa hay (average of three analyses) there are 17.60 pounds of crude protein, 3.08 pounds of crude fat, 39.31 pounds of nitrogen-free extract, and 22.63 pounds of crude fiber. For this hay, according to the latest investigations, it has been found that of the protein about 70 per cent. is digestible; of the fat, 51 per cent.; of the crude fiber, 46 per cent.; and about 68 per cent. of the nitrogen-free extract can be digested. Hence, in 100 pounds of alfalfa hay there would be 12.32 pounds of digestible protein, 1.57 pounds of digestible fat, 26.73 pounds of digestible nitrogen-free extract, or starchy material, and and 10.40 pounds of digestible fiber.

Nutritive Ratio.—The different feeding stuffs vary very much in their composition; peas and beans, and the concentrated foods in general, contain large amounts of protein, or muscle-forming ingredients, and very little of the non-nitrogenous materials; others, like the potato, corn, etc., have much starchy matter combined with small quantities of albuminoids; and, again, as in the case of the vegetables as a whole, we have small amounts of both carbohydrates, or fat-producers, and nitrogenous, or muscle-formers.

The proportion of these two important elements of the cattle foods is termed the ***nutritive ratio;*** in other words, the latter is the ratio of the digestible protein to the sum of all the remaining nutrients in the food. In estimating this sum, the figure denoting the amount of fat is multiplied by 2.25, because it has been ascertained by experiment, as before stated, that about 2.25 times as much heat is developed by the consumption of a pound of fat as by the same quantity of sugar or starch. This product is added to the weight of the carbohydrates, and the sum divided by the figure for the protein, the quotient being the nutritive ratio.

To illustrate this: Let us take, again, alfalfa hay, which contains, as previously noted, 12.32 per cent. of digestible protein, 1.57 per cent. of fat, 26.73 per cent. of digestible nitrogen-free extract, and 10.40 per cent. of digestible fiber. The fat percentage (1.57), multiplied by 2.25, amounts to 3.53; this added to the figure for the fiber and carbohydrates, 37.13, equals 40.66, which divided by 12.32, the per cent. of protein, gives 3.3. Hence the nutritive ratio is 1:3.3; in other words, there is in alfalfa hay 1 part of protein, or nitrogenous matter, to 3.3 parts of non-nitrogenous, or starchy material. The ratio is "wide," and termed a carbonaceous one, when the amount of protein to the remaining ingredients is small. A "narrow," or nitrogenous ratio, is one where the reverse is the case; that is, the amount of protein is considerable when compared with that of the carbohydrates, as in the example just given.

The data for the total dry matter and digestible nutrients in 100 pounds of the different feedstuffs, are presented in table II.

TABLE II.—DRY MATTER AND DIGESTIBLE NUTRIENTS IN 100 POUNDS.

FEED STUFFS.	Dry Matter in 100 lbs.	DIGESTIBLE NUTRIENTS IN 100 LBS.			Nutritive Ratio.
		Protein.	Carbo-Hydrates.	Fat.	
Green Fodder.					
Alfalfa	20.0	3.7	7.3	.6	1: 2.3
Alfileria	20.0	2.1	8.5	.7	1: 4.8
Australian saltbush	23.5	2.5	9.2	.3	1: 3.9
Barley	21.0	1.9	10.2	.4	1: 5.8
Clover, red	29.2	2.9	14.8	.7	1: 5.6
Corn, Indian	20.7	1.0	11.6	.4	1:12.5
Corn, Kaffir	23.9	1.7	12.1	.6	1: 8.0
Cow pea	16.4	1.8	8.7	.2	1: 5.1
Flat pea	56.5	6.2	14.2	1.0	1: 2.4
Horse bean	15.8	2.2	7.1	.2	1: 3.5
Hungarian grass	28.9	2.0	16.0	.4	1: 8.5
Marsh ("Briston") grass	50.0	2.6	24.4	.9	1:10.2
Modiola decumbens	20.0	1.8	9.0	.5	1: 5.3
Oats	37.8	2.6	18.9	1.0	1: 8.1
Orchard grass	27.0	1.5	11.4	.5	1: 8.3
Peas and oats	16.0	1.8	7.1	.2	1: 4.2
Rye	23.4	2.1	14.1	.4	1: 7.1
Sacalin, leaves	17.7	3.8	6.3	.8	1: 2.1
Sacalin, stalks	17.8	.8	7.5	.2	1:10.0
Snail clover	18.8	2.0	8.2	.6	1: 4.7
Soya bean	24.9	3.2	11.0	.5	1: 3.8
Sorghum	20.6	.6	12.2	.4	1:21.8
Silage.					
Barley	26.0	1.8	12.7	.9	1:11.7
Clover	28.0	2.0	13.6	1.0	1: 7.9
Corn	24.6	1.3	13.5	.6	1:11.7
Oat	28.0	1.5	14.8	.9	1:11.0
Orchard grass	23.0	1.1	10.6	1.0	1:11.4
Roots, Beet Pulp, etc.					
Artichokes	20.0	2.0	16.8	.2	1: 8.7
Beet, mangels	9.1	1.1	5.4	.1	1: 5.1
Beet, sugar	15.7	1.6	11.9	.1	....
Beet pulp, fresh	10.0	.9	7.3	.1	1: 8.2
Beet pulp, silage	11.1	1.2	7.7	.2	1: 6.8
Beet molasses	74.3	3.7	52.4	....	....
Cabbage	15.3	1.8	8.2	.4	1: 5.1
Carrots	11.4	.8	7.8	.2	1:10.4
Parsnips	11.7	1.6	11.2	.2	1: 7.3
Pie melons	5.5	.7	3.3	.2	1: 5.4
Potatoes	21.1	.9	16.3	.1	1:18.4
Pumpkins	9.1	1.0	5.8	.3	1: 6.6
Sugar beet crowns	18.1	1.7	12.7	.07	1: 7.5
Sugar beet leaves	11.3	1.7	4.6	.03	1: 2.7
Sugar beet tops	12.9	1.7	6.5	.05	1: 3.8
Turnips	9.5	1.0	7.2	.20	1: 7.7
Hay.					
Alfalfa	89.1	12.3	37.1	1.6	1: 3.3
Australian saltbush	91.5	6.5	36.8	1.0	....
Barley, average	91.5	5.8	43.1	1.6	1: 8.1
Clover, alsike	90.3	8.4	42.5	1.5	1: 5.5
Clover, bokhara	91.0	8.7	39.4	1.9	1: 5.0
Clover, bur	89.9	7.3	41.2	1.8	1: 6.2
Clover, crimson	90.4	10.5	34.9	1.2	1: 3.6

TABLE II.—Dry Matter and Digestible Nutrients in 100 Pounds. (*Continued.*)

Feed Stuffs.	Dry Matter in 100 lbs.	Digestible Nutrients in 100 Lbs.			Nutritive Ratio.
		Protein.	Carbo-Hydrates.	Fat.	
Hay (*Continued*).					
Clover, red	84.7	6.8	35.8	1.7	1: 5.8
Clover, snail	89.9	9.6	39.4	1.8	1: 4.5
Clover, white	90.3	11.5	42.2	1.5	1: 4.0
Clover, wild yellow	90.5	10.1	36.6	2.4	1: 4.1
Cow pea	89.3	10.8	38.6	1.1	1: 4.7
Flat pea	90.0	15.3	36.0	2.4	1: 2.7
Foxtail	88.0	4.3	41.4	.9	1:10.1
Hungarian grass	92.3	4.5	51.7	1.3	1:12.1
Johnson grass	89.2	3.2	42.3	.8	1:13.8
Mixed	92.4	4.4	47.3	1.7	1:11.5
Oat	89.9	4.5	43.7	1.5	1:10.5
Orchard grass	90.1	4.9	42.3	1.4	1: 8.3
Rye grass, perennial	86.0	6.1	37.8	1.2	1: 6.6
Soya bean	88.7	10.8	38.7	1.5	1: 3.9
Vetch	88.7	12.9	37.5	1.4	1: 3.2
Wheat	91.2	3.6	46.1	1.1	1:13.2
Wild hay	90.0	3.4	44.1	1.1	1:13.6
Other Dry, Coarse Fodder.					
Alkali weed	86.6	5.5	38.6	2.2	1: 7.8
Barley straw	85.8	.7	41.2	.6	1:60.8
Corn fodder	57.8	2.5	34.6	1.2	1:15.0
Gourd vine, "mock orange"	86.1	5.1	37.5	1.3	1: 7.8
Lima bean straw	90.0	5.4	38.8	1.2	1: 7.7
Oat straw	90.8	1.2	38.6	.8	1:33.6
Soya bean straw	89.6	2.3	40.0	1.1	1:18.4
Wheat straw	90.4	.4	36.3	.4	1:93.0
Grains and Other Seeds.					
Barley (crushed)	90.0	9.6	63.5	2.1	1: 7.1
Broom corn	87.3	8.1	61.6	3.0	1: 8.4
Bur clover seed	93.4	17.2	38.7	4.3	1: 2.8
Corn, Indian	89.4	7.8	66.7	4.3	1: 9.8
Corn, Egyptian	87.4	8.0	64.3	3.0	1: 8.9
Corn, Kaffir	90.7	7.5	70.5	2.6	1:10.3
Cow pea	85.2	18.3	54.2	1.1	1: 3.1
Flaxseed	90.8	20.6	17.1	29.0	1: 4.0
Oats	89.0	9.2	47.3	4.2	1: 6.2
Rice	87.7	5.3	67.6	.3	1:11.8
Rye	88.4	9.9	67.6	1.1	1: 7.1
Soya bean	89.2	29.6	22.3	14.4	1: 2.0
Sorghum	87.2	7.0	52.1	3.1	1: 8.4
Sunflower	92.5	12.1	20.8	29.0	1: 7.1
Wheat, plump	88.5	9.5	49.9	1.4	1: 5.6
Wheat, shrunken	91.7	13.7	47.6	1.4	1: 3.7
Mill and By-Products.					
Brewers' grains, dry	91.8	15.7	36.3	5.1	1: 3.0
Brewers' grains, wet	24.3	3.9	9.3	1.4	1: 3.2
Cocoanut oil-cake meal	85.9	16.4	42.4	9.7	1: 3.9
Corn meal	88.0	6.4	66.3	3.4	1:11.5
Cottonseed meal	90.2	41.1	15.4	11.0	1: 1.0
Gluten feed	92.2	20.4	48.3	8.8	1: 3.3
Gluten meal	91.8	25.8	43.3	14.0	1: 2.9
Linseed oil-cake meal, N.P.	89.1	26.1	38.5	6.5	1: 2.0
Linseed oil-cake meal, O.P.	90.7	24.4	24.0	16.7	1: 2.5

TABLE II.—DRY MATTER AND DIGESTIBLE NUTRIENTS IN 100 POUNDS. (*Continued.*)

FEED STUFFS.	Dry Matter in 100 lbs.	DIGESTIBLE NUTRIENTS IN 100 LBS.			Nutritive Ratio.
		Protein.	Carbo-Hydrates.	Fat.	
Mill and By-Products (*Cont.*).					
Malt sprouts	86.7	15.6	35.8	2.0	1: 2.6
Mixed feed	89.4	9.6	47.4	3.0	1: 5.6
Palm nut meal	89.6	16.0	52.6	9.0	1: 4.6
Pea meal	89.5	16.8	51.8	.7	1: 3.2
Peanut meal	89.3	42.9	22.8	6.9	1: 0.9
Rice bran	89.5	10.7	41.8	10.6	1: 5.9
Rice hulls	89.0	2.7	30.8	.8	1:12.1
Crushed barley	90.0	9.6	63.5	2.1	1: 7.1
Rye bran	88.4	11.5	50.3	2.0	1: 4.8
Shorts	90.2	12.2	47.9	2.9	1: 4.5
Wheat bran	88.3	11.2	42.2	2.5	1: 4.3
Wheat middlings	88.3	12.2	53.4	3.8	1: 5.1
Wheat screenings	88.4	8.1	48.7	1.8	1: 6.6

POTENTIAL ENERGY.

The measure of food as regards its fuel value is made in terms of "potential energy," the unit of which is the *calorie*, or the amount of heat necessary to raise the temperature of a kilogram of water 1° Centigrade, or one pound of water 4° Fahrenheit. Instead of this unit we may use a unit of mechanical energy, the foot-ton, which is the force that would lift one ton one foot, one calorie being equal to about 1.53 foot-tons.

Professor Rubner found, in experiments made in the physiological laboratory at Munich, the quantities of materials which were equal to 100 of fat to be as follows:

Nutritive Substances, Water-Free.	As determined by direct experiment with Animals.	As determined by Calorimeter.
Myosin (proteid of meat)	225	213
Lean meat	243	235
Starch	232	229
Cane sugar	234	235
Grape sugar	256	235

Taking the ordinary food materials as they come, the following general estimate has been made for the average amount of energy in one gram of each of the classes of nutrients:

Potential Energy in Nutrients of Food.

	Calories.	Foot-Tons.
In one gram protein	4.1	6.3
In one gram fats	9.3	14.2
In one gram carbohydrates	4.1	6.3

These figures mean that when a gram of fat is consumed, be it fat of the food or body fat, it will, if its potential energy be all transformed into heat, yield enough to warm 9.3 kilograms of water 1° Centigrade, or, if it be transformed into mechanical energy, such as the muscles use to do their work, it will furnish as much as would raise one ton 14.2 feet, or 14.2 tons one foot. The potential energy of the protein or carbohydrates is less than one-half that of the fat. These figures, as stated by Professor Atwater, are not absolutely accurate, and may be revised by future research in the subject.

COMMENTS ON VARIOUS FEED-STUFFS.

SILAGE AND VEGETABLES.

One of the chief requisites of a ration for profitable milk-production is that it be succulent, by which is meant that a portion of the ration contains a large percentage of water. This watery condition, or succulency, adds to the palatability of the food, and also seems to have a beneficial physical effect upon the animal digestion. The cow, therefore, eats a larger quantity of food, digests and assimilates it more thoroughly, and consequently gives a larger flow of milk. Although the major portion of California does not have the long cold winters to which the Eastern States are subject, and where it is an absolute necessity to store large quantities of food, both succulent and dry, still every section of our State has a longer or shorter period during the year when pastures are dry. The provident dairyman, therefore, anticipates these dry months, and either lays in a store of green food beforehand, or has some growing which he may cut and feed to his cattle.

Roots.—Several of the vegetables are valuable in supplying succulence for the ration. Among the root class the one in most common use is the mangel wurtzel beet, because very large quantities can be grown per acre and because it is palatable to all kinds of live stock. Carrots are also used in some sections, and they have the advantage of containing a slightly larger amount of dry-matter than mangels. Of all the roots, moreover, none are more relished by horses than carrots. Sugar beets are not found profitable to grow for feeding stock, because they yield so small a tonnage in comparison to mangels, and the greater cost of growing and gathering can only be undertaken on the ground of their greater value for sugar. Potatoes contain about twice as much dry matter as mangels and three times as much carbonaceous material. They are, therefore, of greater food value, but, like sugar beets, have too high a commercial value as human food to make them profitable for stock.

Squashes.—Another class of vegetables which are useful and easily grown is that of the melons or squashes. A very familiar example is the so-called *pie-melon*, an analysis of which is found in Table I. This, like the ordinary field pumpkin, can be produced readily in large quantities on most lands, and it ripens at a time when green food is likely to be scarce. All of these vegetables when fed to dairy stock produce an increased milk yield, which is more than commensurate with their actual content of food substance. This is because of their palatability, beneficial effect upon digestion, and the addition of a wholesome variety to the ration. Any of the vegetables named may be fed with profit to swine and poultry when in confinement, and to sheep especially during the nursing period.

Silage.—One of the most economical means of preparing succulent food for seasons of drought and for supplementary feeding is by the use of the silo. It is, no doubt, generally understood that the silo, as at present constructed, is a huge tank having perpendicular walls and being made as nearly air-tight as is convenient. The usual size for the silo is fifteen to twenty feet in diameter and thirty feet high. Into the silo is put the green fodder immediately after being cut fresh in the field. The most common crop for ensiling is Indian corn, which is, moreover, the most profitable plant to grow for this purpose. At one harvest it furnishes a larger tonnage per acre than any other crop. The stalks, which if cured dry would be largely wasted, are kept in so soft a condition in the silo as to be completely eaten by the stock. Other plants, such as alfalfa, barley, oats, and orchard grass, are sometimes ensiled, but we would not recommend their general use except in seasons or localities where corn may not at the time be available, or in case they might otherwise be rendered more or less useless if cured dry; as, for example, the first cutting of alfalfa with its usual mixture of foxtail. Almost any plant grown on the ranch may be ensiled. The chief question is, what can be most profitably made the main crop for the purpose? The proof is abundant that Indian corn is the most profitable. The sorghums and sweet corn do not answer well for ensiling because of their high content of sugar, resulting in too much fermentation in the silo.

No better combination of foods for feeding cows in the stable can be imagined than alfalfa hay and corn silage, and possibly a little grain, although a fairly well-balanced ration can be made up without grain. In such feeding it is best to give hay and silage each once a day. The amount of silage per head ranges from thirty-five to sixty pounds daily, depending upon the size and appetite of the animal and upon the supply of silage. The cattle will eat corn silage at all seasons of the year, even when on good alfalfa or other green pasture; but if the supply be limited it can be most profitably fed when pastures are dry, or if the cattle should be kept off them because of heavy rains or until the grass is of sufficient age and size to be of value. If the dairymen will erect silos and have their cows calve in the fall instead of spring they can secure as large a flow of milk during the season when dairy products are usually high-priced as they now have during the low prices of the spring months. Corn silage may be fed with profit to sheep as well as cattle, but not to other stock. Alfalfa silage is fed successfully to all farm stock, including swine and poultry. Horses working hard should be given such watery food in very small quantities; while those at light work or doing nothing may be fed more, and will even make profitable use of some corn silage.

Soiling.—Another method of providing succulent food is to cut the fodder green and feed immediately to the stock. This method is known as "soiling." Any of the ordinary fodder plants may be used in this way—the most common being any of the corns, sorghums, oats and peas, cereal grasses and the like. If this practice is followed the same rule would apply as in the case of silage—to raise the crop which will produce the most and best food per acre. "Soiling" presupposes that the stock are being kept in small pastures or in corrals, or at least have but little feed on their range. It also calls for more labor than is necessary if the stock could harvest their own food, but less land is required to maintain the same number of cattle than if they depended wholly upon pasturage. The matter then lies between soiling on the one hand with less land and more labor, and pasture on the other with more land and less labor. With plenty of land available and labor high, we do not expect an extended adoption of the soiling method in California for some years to come. The more general use of the silo will also tend to reduce the soiling period, because experience shows that it is cheaper to provide green food for the year by one filling of the silo than by the daily cutting of standing fodder.

ALFALFA.

The large amount of alfalfa grown in the interior valleys of the State and its great value as a stock food render it an important element in the development of the animal industries, and one worthy of careful study and experimentation. Two factors make alfalfa of great use to the farmer and stockman—one is the large yield of pasture or hay that he can produce during the year, and the other is the high content of protein which alfalfa contains. Alfalfa hay of good quality carries so much of this important and usually costly element that a glance at the tables of analyses shows that twenty pounds of hay contains as much protein as is required in the balanced ration of an ordinary sized milch cow. Table III also shows the relative amount of digestible protein in a ton of material and the cost of protein per ton of the various common feedstuffs and of the more common hays. These comparative figures show how valuable a fodder alfalfa is. Almost all of the coarse fodder grown upon the ranch is relatively rich in carbohydrates and relatively poor in protein. This is particularly true of the cereal hays, straw, corn fodder and the like. With these only the feeder cannot make a good ration, and what he needs to buy is protein. He usually buys concentrated foods because of their richness in protein, and also pays for them on the basis of their protein content. Were he able to raise alfalfa or to buy it at a reasonable price, he could feed his cattle much more cheaply, and undoubtedly with as good results. This fact is brought out by Table III, showing the relative cost of protein per pound as furnished by the different foods. These prices are taken to represent as nearly as possible the market values at the time of writing. Calculations of this kind can never be arbitrary, owing to the fluctuation in prices, but they show how the careful purchaser may be able to compare food values at any season of the year.

TABLE III.—Cost of Protein in Various Foods as Governed by the Cost of the Food and its Content of Digestible Protein.

Food.		Protein.	
	Price per ton.	Pounds per ton.	Price per pound.
	Dollars.		Cents.
Corn	26.00	156	16.7
Wheat	20.00	190	10.5
Barley	17.00	192	8.8
Oats	25.00	184	13.6
Rye	18.00	198	9.1
Wheat bran	17.00	224	7.6
Wheat shorts	16.00	244	6.6
Wheat middlings	18.00	244	7.4
Rice bran	14.00	214	6.5
Rye bran	14.50	230	6.3
Coacoanut oil-cake meal	17.00	328	5.2
Linseed oil-cake meal	25.00	522	4.8
Cottonseed meal	30.00	822	3.7
Mixed feed	15.00	192	7.8
Malt sprouts	15.00	312	4.8
Alfalfa hay	8.00	246	3.3
Wheat hay	9.00	72	11.1
Barley hay	9.00	116	7.8
Oat hay	9.00	90	10.0
Straw	3.00	16	19.0
Corn silage	2.00	26	7.7

We are not yet prepared to say that by the liberal feeding of alfalfa, concentrated foods may be dispensed with entirely. As a general principle it would seem that a small amount of grain could be profitably fed at all times. Much and careful experimentation is needed to decide the often-asked question, "Does it pay to feed grain with alfalfa?" We hope to be able to undertake this experimental work in the near future.

SALTBUSHES.

The saltbushes have a two-fold value in that they are not only valuable forage plants but can be cultivated in soils containing alkali beyond the limit of tolerance for any other plant of similar food-value. Of these the *atriplex semibaccata* is the only one which has received any extended attention in this State.

It is specially worthy of mention that while the saltbushes differ materially botanically, and are not of equal adaptation, there is very little preference so far as chemical composition is concerned. But much further experimentation will be required before the same can be said of them physiologically, or with respect to nutritive values.

The choice of the best variety for a special locality would depend on soil adaptation and the results of feeding experiments.

Hays.—An examination of the analyses of the air-dried materials shows that the saltbushes compare very favorably in nutritive value with the other hays mentioned in table I. The average protein content, 12.89, is twice that noted for wheat hay, 50 per cent. more than the figure given for oat hay, and is only exceeded by bur clover and alfalfa. The average percentages of fat and starchy matter in the saltbushes are less than those found in cereal hays. But in the case of the latter nutrient, the average is almost identical with the figures named for alfalfa and bur clover.

Digestibility.—As before stated, much more experimentation is required before we can definitely assert that these saltbushes have as high digestive coefficients as alfalfa and the ordinary hays. Feeding experiments are called for in this direction, and in some cases urgently so.

In making up a ration we would assign to the saltbush hay about the same digestive coefficients as those for oat hay. The digestibility would be greatly increased if the material were cut into small pieces, as it is a well-known fact that much more nutriment is derived from a given amount of fodder, more particularly by the horse and other solipeds, if it is cut up than if fed as harvested. This has been practically proved by many of the large livery stables, both here and abroad.

Feeding.—It is not advisable to feed the saltbushes alone, particularly in the air-dried state, owing to the high percentage of saline ingredients, and the general uninviting appearance and condition of the saltbush hay. In cases of emergency, however, sheep and cattle have existed altogether on this material through an entire season.

Mixed vs. Unmixed Foods.—From the large number of favorable reports, it would seem that many of the failures were due mainly to irrational feeding. In some cases animals which had never seen the salt-bush were given quantities of the unmixed material and were expected to eat it with relish. Such a method of procedure is, to say the least, ill advised. Any alteration in the food should be slow and gradual. It would be most unwise to substitute *A. semibaccata* for a cereal hay. The better plan would be to feed a very small amount of saltbush with considerable hay; then increase by degrees the quantity of saltbush and decrease that of cereal hay until the proportions are about equal. If the green saltbush were used, then the hay should constitute about one-third of the roughage of the ration.

Utilization of Straw.—The value of straw as a dilutant is becoming more appreciated every year. But it must be remembered that straw is dry, fibrous, and unpalatable, and consequently requires a succulent material to be used in conjunction with it. For this reason it is not desirable to feed the *saltbush hay* with straw. The green, however, could very advantageously be utilized, more particularly if both feeds were cut up and well mixed. By this method the farmer is not only able to use alkali land which has been considered worthless, but can use in conjunction with the crop from this land another material which has been deemed of little feeding value. The economy of this plan is apparent without discussion.

Silage and the Saltbush.—Silage could be fed profitably with either the green or air-dried saltbush; in the latter case, the dryness of the saltbush would be offset by the succulency of the silage. The amount of silage to be fed per day would depend greatly on the animals and the supplementary materials of the ration. The succulency of the fresh saltbush would be preserved and the digestibility of some of its fibrous parts increased if it were siloed. With some other material a salty relish would thus be imparted to the silage.

OTHER COARSE FODDERS.

Alkali Weed.—The *Centromadia pungens*, commonly called the yellow-blossoming alkali weed, or tall tar-weed, grows luxuriantly, attaining a height of from four to six feet on lands of the San Joaquin valley which are not too strongly contaminated with alkali. In this respect it materially differs from the *Atriplex semibaccatum*, or Australian saltbush, which thrives on soils so heavily impregnated with alkali that other cultures are not possible.

A comparison of the amounts of this fodder digestible with some well known and commonly used hays would emphasize the value of this plant for stock feeding. The total nutriment, as indicated by the fuel value in one pound, 919 calories, would place this feed-stuff low on the list. But when we compare its digestible flesh-formers, 6.15 pounds, with the corresponding content of other hays; we note that it rates almost as high as barley hay which stands second; alfalfa ranking first with 12.30 pounds, or about twice that given for either barley hay or the alkali weed. Hence we see that the more of the alkali weed that can be used in the ration the more highly nitrogenous will it be and consequently the more beneficial for the animal.

Experience has shown that stock will not eat *Centromadia* in the green state. This fact may be due to the presence of an essential oil and resin which probably disappears during the drying or curing of the plant, or to the spiny tips on the leaves, similar to those found on the thistle, which soften as the plant becomes older and dryer. By siloing the green material the above objections might be overcome and most certainly would be if the spiny tips were the trouble. If no unpleasant flavors are imparted to the milk by the use of this weed, then the dairyman has in the *Centromadia pungens* a most valuable addition to his list of feed-stuffs.

Gourd Vines (Cucurbita foetidissima).—This vine is sometimes called mock orange. During the past dry seasons it has served in the southern part of the State as a substitute for hay, and, according to some reports, to good advantage. This plant admits of two or three cuttings annually.

A glance at the analysis, given in table I, page 5, shows that, chemically speaking, this fodder is a rich one, but we are ignorant of its physiological value; that is, we do not know just how much of the different nutrients are digestible by cows and horses. The figures stated for the amounts digestible in 100 pounds have been calculated on the assumption that these vines are as digestible as dried corn fodder. On that basis there is as much nutriment in the gourd vines as in any of the cereal hays.

Foxtail.—In this connection it is of interest to note the feeding value of foxtail (barley grass), which, when considered as hay, is found of equal nutritive value to oat hay. A ration made up wholly of alfalfa and foxtail hays in the proportion of 15 pounds of alfalfa to 12 pounds of foxtail, would have approximately the same composition and food value as ration No. 3 above, of alfalfa and barley hays. Owing, however, to the disagreeableness and injury to animals from the beards of the foxtail when dry, its chief value to the stockman is as pasture or as silage, where the beards are so softened as to render them harmless. On account of the richness of foxtail in carbonaceous material as compared to alfalfa, the latter is made a more useful ration by the presence of foxtail if it can be fed either in green pastures or from the silo.

GRAINS AND BY-PRODUCTS.

Plump and Shrunken Wheat.—"Which is the better feed for laying hens, shrunken or plump wheat," is a question which has been agitating a number of poultry men in this State, and to intelligently answer it two samples of wheat received from Hanford have been analyzed, with the result that in the plump wheat the percentage of starch, etc., is considerably higher than the corresponding figure for the shrunken wheat; while the reverse is noted for the rating of protein, that of the latter sample being almost 50 per cent. greater than that yielded by the former, as is seen by the figures 17.10 and 11.70 per cent., respectively. This fact alone is sufficient to warrant a feeder purchasing shrunken in place of plump wheat as a food for laying hens.

It is barely possible that the digestion-coefficient for protein in the shrunken wheat may not be as high as that for the plump, but this question we will settle at the earliest opportunity by a digestion experiment with our hens. It must not be forgotten, however, that the figure 11.70 for albuminoids in the plump wheat is a trifle below the average; and while another example of two similar wheats would in all probability show the shrunken sample to be richer in nitrogen, there might not be such a marked difference as we have between the two lots under discussion.

Wheat, Bran, Middlings, Etc.—Throughout the whole country no grain product is used more universally for stock feeding than the by-products of wheat, the chief of which are bran and middlings. This is partly due to the fact that wheat is almost wholly used for human food, and in the manufacture of the best grades of flour the bran and middlings must be removed. Another feature which renders them so popular is that they are relished by all kinds of live stock, and that in the case of bran it may be fed *ab libitum* without injury to the animal. Our analyses show the middlings to be slightly richer in the various nutrients than bran, but the proportion of the nutrients is such that bran has the narrower nutritive ratio. Bran contains much more fiber than middlings, and is so much coarser that it is not so well adapted to feeding pigs and very young calves. Pigs do not relish foods as coarse as bran, oats, and the like, and it is therefore better economy to provide them with the finer materials like middlings. One feature of bran often overlooked is its high content of mineral matter. This, together with its richness in protein, makes it one of the most desirable foods for growing stock, as calves or colts, where bone and sinew need to be developed.

"*Shorts*" are classed among the by-products of wheat, and are shown by our analysis to have very nearly the same composition as middlings. The two names, middlings and shorts, are often used interchangeably, referring to the same article. Shorts sometimes consist largely of ground-over bran with some of the finer portions of ground wheat mixed in. For young pigs and calves middlings are the more certain article to depend upon, while for older animals shorts may be used instead, if the price warrants.

"*Mixed feed*" is a very uncertain article, and depends for its value more upon the honesty of the manufacturer than upon the name. It may be of good material, as our analysis shows it to be, or it may contain large quantities of mill-sweepings, ground oat-hulls and other matter of little value.

Gluten Feed and Gluten Meal.—These are two by-products resulting from the manufacture of starch and glucose from corn. The corn grain may be roughly analyzed as follows: first is the outside layer of bran or hull; next comes a hard, flinty layer, which is very rich in protein, and which is called the gluten layer; inside this coating we find the main portion of the kernel, consisting chiefly of starch, and finally the germ of the seed. In the process of manufacturing starch and glucose the hull, gluten layer and germ are thrown aside. When all three are mixed together we have what is known in the market as "gluten feed." When the gluten layer is kept separate we have what is known in the market as "gluten meal." The hull of the corn is of comparatively little food value because of its coarse fibrous nature. The germ is rich in protein and fat, and is readily digested. In order to dispose of the hulls to advantage, the manufacturer mixes and grinds them with the germs and gluten layers, and he often does the animal no unkindness in the operation. The gluten layer alone, or gluten meal, is a very rich and heavy material, and should not be fed in larger quantities than three or four pounds per day. It is therefore sometimes fed to the injury of the animal by careless or inexperienced men. Gluten feed, however, because it contains the hulls, is a lighter material, not so rich, and may safely be fed in larger quantities up to six or seven pounds per day. It contains about twenty per cent. of digestible protein, while the gluten meal contains about twenty-five per cent. They are both, therefore, of great value as furnishers of protein for farm stock.

While this is the general distinction between gluten feed and gluten meal, the various manufacturers have introduced so many private and trade names that the purchaser is not always sure of his article until he sees it. Some of the more common names are "Chicago Gluten," Buffalo Gluten" "Cream Gluten," and the like. The chances are, however, that the buyer will obtain gluten *feed* as described above unless he makes an especial request for gluten *meal*. So far as we know, neither of these foods is in the California market, but their value will undoubtedly lead our dairymen to call for them before many years have passed.

Oil-Cake Meals.—The principal value of these meals lies in the high percentage of protein which they contain. The richest of all in this element is cottonseed meal, which, according to our analysis, shows 41.1 per cent. of digestible protein. "New process (N.P.)" linseed meal shows 26.1 per cent., "old process (O.P.)" linseed meal shows 24.4 per cent., and cocoanut meal 16.2 per cent.

Cocoanut meal is a by-product resulting from the extraction of oil from the cocoanut of commerce. So far as the United States is concerned, it is distinctively a Pacific Coast article, as it is not much known east of the Rockies. The present market price is about the same as wheat bran, and since it contains 16.4 per cent. of digestible protein as against 11.2 per cent for bran, the cocoanut meal is much the cheaper to purchase as a furnisher of the nitrogenous element. It cannot, however, be fed so freely as bran, and it is doubtful if more than four pounds daily per head can be safely fed for any length of time. The one objection to cocoanut meal is its lack of keeping qualities. It is likely to become rancid if stored for several weeks, in which condition it is not relished by the stock, and if fed to dairy cows is apt to flavor the milk. When fresh it has a sweet and nutty flavor, which is highly relished by all stock.

The *linseed meals* are a by-product from the extraction of oil from flaxseed. The "old process" meal is the result of such extraction by means of pressure, while by the new process the oil is dissolved out of the ground flaxseed by means of naphtha. The odor of naphtha is afterwards driven off by steaming. In the new process the oil is more thoroughly extracted, and thus less remains in the meal than by the old process. The analysis of "old process" linseed meal in Table II is of one sample, and can hardly be taken as an average of this class of meals. The linseed meals have a laxative effect upon the digestion, and thus it is not well to feed more than two pounds per head daily to dairy cows. They tend also to make a soft butter fat. When fed in normal quantities they are very beneficial to the animal digestion, and impart a soft glossy appearance to the hair, and therefore become a useful portion in the rations of all farm stock.

Cottonseed meal comes to us from the cotton-growing States as a by-product from the extraction of oil from cottonseed. It is not quoted in our market, but dealers in feeding stuffs tell us that they will order it for any party or parties who will use a carload or more. In sections where alfalfa is not grown or readily obtained, cottonseed meal is one of the cheapest foods to buy to furnish protein, as shown in Table III. This is true although its price in the market may be higher than that of any of the other concentrated foods. Three pounds of this meal furnishes nearly half as much protein as is required in the day's ration of an average-sized cow. Thus it is not usual that more than two pounds per head be fed in addition to the protein which is provided by the other part of the ration. It is not well to give more than four pounds per head, on account of the constipating effect of the meal upon the animal. In feeding dairy cows it is also found to produce a hard butter fat. Cottonseed is most largely used for cattle feeding, both beef and dairy, and with invariably good results. It has proven so detrimental to swine of all ages and to young calves, that deaths have been reported as resulting from feeding it to them. So far as we know it has not been experimented with to any extent in feeding horses.

SUGAR-BEET TOPS, MOLASSES, AND PULP.

Sugar-Beet Tops.—It is stated by some feeders that sugar-beet tops is one of the best feeds available for the production of a firm butter. The Station expects in the near future to make some elaborate chemical tests on such butters.

The sugar-beet tops consist of leaves and crowns of the root (all that part which has a greenish tinge), in the proportion of 76 per cent. of leaves and 24 per cent. of crown.

The analyses of leaves, crown, and tops are given in Table I.

An inspection of the figures showing the composition and nutritive value of the sugar-beet tops shows that water constitutes about seven-eighths of this material. One hundred pounds of the fresh substance is found to contain 8.25 pounds of digestible nutrients, proportioned as follows: protein, 1.71 pounds; carbohydrates, 6.49 pounds; and fat, .05 of a pound, with a valuation of $1.58. The analysis and valuation previously published were obtained from an Eastern source; our late work proves the tops to rate the same for protein, but to be slightly richer in carbohydrates, thus increasing the value from $1.40 to $1.58. The fertilizing value is about $1.65.

From these figures we see that the material as such is worth more as a fertilizer than as a cattle food. The above estimate of the tops as a fertilizer does not include the vegetable matter, which as a green-manure has considerable value. But it is said that if the tops are used as a food and the manure saved, about three-fourths of the fertilizing value of the original substance is still retained. While this is true theoretically, it is hardly ever so practically; particularly with reference to the nitrogen, the most costly of the fertilizing elements.

In very few instances, unless the animals are pastured, is the urine saved to the soil, and this part of excreta contains the major part of the nitrogen.

The nitrogen in the manure is not by any means all available, at best not more than fifty per cent., and in many cases not even so much; owing to the careless in handling of the dung. On this basis the fertilizing value of the manure would be about 80 cents (three-fourths of the potash and phosphoric acid and one-fourth of the nitrogen); this added to the value as a food, $1.58, increases the net value to $2.38, and the difference (73 cents) between this sum and the fertilizing worth, is fully made up in the green-manurial value of the vegetable matter in the tops.

It is thus seen that theoretically, at least, the tops are of equal value in whichever way they are used; therefore it would be foolish for a man who did not own cows to buy them and burden himself with a new industry for the sake of using the beet tops economically. But for those who have animals a wise choice could be made by considering the general conditions of land, food, labor, etc., without regard to figures and values.

We must not forget in this connection that the sugar-beet tops *alone* will not constitute a balanced ration, or even approach it. They can only be used as a portion of the roughage food given to the animals.

On account of the bitter taste imparted to the milk by the beet tops, their use as a feed is not recommended in dairies supplying milk to be consumed as such.

It is claimed by some authorities that an excessive use of sugar-beet tops will prove injurious to the animals on account of the oxalic acid present; hence the conjoined use of lime in countries where the leaves are siloed.

Beet-Sugar Molasses.—In Europe a number of "molasses feeds" have been proposed. One of these, which has been used to a considerable extent, is made up of bran four parts, molasses three parts, and palm-nut cake one part. Molasses is also mixed with dried blood, with peat*, and with beet pulp. The latter mixture is dried, and possesses good keeping qualities.

In a number of reported European experiments molasses feeds were tested with dairy cows. No deleterious results were noticed, even when four to five pounds of molasses was fed daily. An extended study of the value of molasses as part of a ration for pigs, steers, milch cows, and horses was recently reported in a French agricultural journal. The principal conclusions from the investigations were as follows: When molasses formed part of the ration of sheep, pigs, and steers, the gains in live weight were rapid. When molasses was fed to milch cows the total milk yield and the amount of fat and milk sugar in the milk were increased. The increase is not regarded as sufficient to warrant the conclusion that molasses is a suitable food for milch cows. Molasses is regarded as an excellent food for horses. It was rapidly eaten, and vigor and weight were maintained when it was added to the ration. It may be advantageously employed for rendering inferior hay or fodder more palatable.

As pointed out in the Canadian Experimental Farm Reports, one-half of the ash of beet-sugar molasses is potash. It is the presence of this, no doubt, that is the cause of the looseness of the bowels when fed above a certain quantity per diem. When symptoms of this condition are observed the quantity of molasses fed should be reduced. Since potash is not retained by the animal, but is eliminated by the kidneys, the urine will be especially rich in this element, and therefore should be carefully preserved by the use of absorbent bedding.

The reports of the Canadian Experimental Farm, already referred to, notes briefly the successful use of sugar-beet molasses in fattening steers. Three to five pounds was fed per day, diluted somewhat, and poured over the cut coarse fodder. It is said that the steers developed a great liking for it, and to all appearances it gave good results. The test was summed up as follows:

"The most important points in favor of this new feeding stuff may be stated as follows: (1) It contains a large percentage of sugar, the most assimilable form of carbohydrates found in cattle feed; (2) it stimulates the appetite, and (3) probably increases the digestibility of the other constituents of the ration."

Sugar-Beet Pulp.—In the process of manufacturing beet sugar there remains a by-product containing a large proportion of water and for which no profitable use has been found thus far, except as a food for stock. Upon the arrival of the sugar-beets at the factory they are first washed and then run through a slicing machine which shreds them into small strips resembling a large size of twine. The shredded beets are placed in large cylinders through which hot water is forced and the sugar thereby dissolved out of the beets. The portion remaining after the sugar has passed off in solution is what is known as beet-pulp, or residue. It is of no further use to the manu-

* When mixed with peat the digestibility is reduced, because the peat acts as so much dead weight.

facturer, who is always ready to dispose of it at a nominal price. Because of its passing through such a soaking process, the beet pulp comes from the factory with a high content of water, which in most cases is about ninety per cent. of its total weight. It is therefore heavy material to handle, and the cost of transportation is likely to be high in proportion to its actual value, either for food or any other purpose. The presence of so much water, however, renders the beet residue of much value for milch cows where other succulent foods, as green pasture, silage or soiling crops, are not available.

Several years of experience in California have proven sugar-beet pulp of value for fattening cattle as well as for producing milk, and the fact is that the larger portion of the beet pulp in the State is consumed by cattle which are being fitted for the butcher's block. It has been fed also to some extent to sheep. Both cattle and sheep eat the pulp so readily that there is scarcely any difficulty about getting them accustomed to it. So far as we are able to learn all those who have fed beet pulp to either of these kinds of stock have been successful except where they tried to make the pulp the sole food. This should never be done for more than a few days at most, because the animal cannot consume enough of such watery food to maintain life and produce milk or meat. Moreover, as a general principle; an animal should never be expected to do its best when confined to a single article of diet.

Storing Beet Pulp.—When a pile of beet pulp has been subjected to the weather for some time the whole exposed surface decays to a depth of six to eight inches, forming a crust which serves as a seal to preserve the under-lying material. Beet pulp may be said, therefore, to silo itself; and the chief points in arranging storage for it are to confine the desired quantity into as small a space as possible and reduce the exposed surface to a minimum. These points are secured by means of silos of various kinds. Since the food value of beet pulp is so small in proportion to its weight, there is no profit in constructing costly storage places; therefore the silo may be cheap, but it must be strongly built.

The silo shown in Figure 1 is used in connection with the beet-sugar factory and dairy in Alvarado. The large trestle carries the beet pulp from the factory, seen in the background, and drops it into the silo below. The silo is 460 feet long, 80 feet wide, and 8 feet deep. It is floored and sided with two-inch plank, and the sloping sides are supported by heavy posts set in the ground and braced with strong timbers. Three tracks run through the silo, one on each side and one in the center, on which a car is drawn by a horse to carry the pulp to the cattle barns several rods distant. A large amount of pulp may still be seen in the photograph of the silo, which was taken March 30, 1901.

Another silo built on the same principle is shown in Figure 2. This may be made of the roughest sort of lumber and of any size to suit the convenience of the feeder. The cut represents a silo twelve feet wide, thirty feet long and six feet deep, and which will hold about two carloads of pulp.

Figure 3 represents a simple and cheap way of constructing a silo by excavating a passage through, or in a hill. The bottoms should

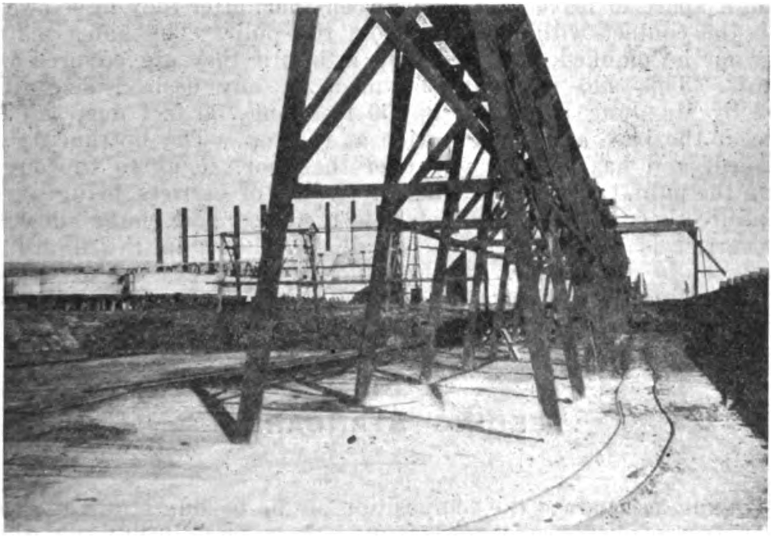

FIG. 1.—Beet-pulp Silo; Alvarado Sugar Works.

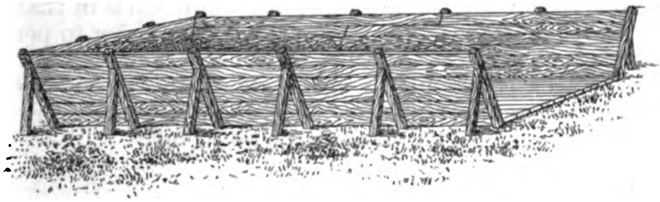

FIG. 2.

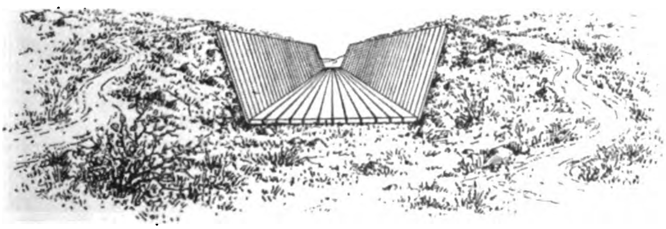

FIG. 3.

be planked in all such cases and means provided whereby the water draining from the pulp may be easily and quickly carried off. The planks should, therefore, set well up from the ground and be far enough apart to leave a crack between them after they have swelled with the contact with moisture from the pulp. The sides may or may not be planked, but less pulp is lost if they are covered with boards. This silo may also be made of any desired size. One used by Mr. John E. Koster is 600 feet long, 50 feet deep, 20 feet wide at the base and 80 feet wide at the top. The bottom only is planked, and has gutterways under the floor, so as to thoroughly drain the pulp. The silo is filled by means of carriers bringing the pulp directly from the sugar factory to the upper part of the silo when the carrier is dumped. In the small silo shown in the figure the filling can be done by driving the wagon alongside the top of the silo and shoveling the pulp into it. None of the silos for preserving beet pulp need any roof.

FEEDING STANDARDS.

Having ascertained the composition of the feeding-stuffs and their digestion-coefficients, the next step is to know just how much the animals require per day to keep them in a normal and healthy condition. These amounts are called *rations*. As might be supposed, this differs with the purpose for which the animal is kept, whether it is growing, being fattened, used for work, or making milk. A horse that is working hard all day in the plow certainly requires more food than one that is doing nothing at all; although, even in that case, the animal needs some of each of the nutrients in order to perform the functions of the body.

The standards commonly in use in this country are the ones set down by the German investigators in this subject, notably Dr. E. Wolff, by whom the following table has been worked out:

TABLE IV.—Feeding Standards.

Pounds per Day per 1,000 Pounds Live Weight.

	Total Dry Matter.	Nutrients. Protein.	Carbo-Hydrates.	Fat.	Total.	Nutritive Ratio.
1. Horse at light work	21.0	1.5	9.5	.40	11.4	1:7
2. Horse at average work	22.5	1.8	11.2	.68	13.7	1:7
3. Horse at hard work	25.5	2.8	13.4	.80	17.0	1:5.5
4. Oxen at rest in stall	17.5	0.7	8.0	.10	8.8	1:4.9
5. Oxen fattening, 1st period	27.0	2.5	15.0	.50	18.0	1:6.5
6. Oxen fattening, 2nd period	26.0	3.0	14.8	.70	18.5	1:5.5
7. Oxen fattening, 3d period	25.0	2.7	14.8	.60	18.1	1:6.0
8. Milch cow	24.0	2.5	12.5	.40	15.4	1:5.4
9. Sheep, wool-producing, coarser breeds	20.0	1.2	10.3	.20	11.7	1:9.0
10. Sheep, wool-producing, finer breeds	22.5	1.5	11.4	.25	13.2	1:8.0
11. Sheep fattening, 1st period	26.0	3.0	15.2	.50	18.7	1:5.5
12. Sheep fattening, 2nd period	25.0	3.5	14.4	.60	18.5	1:4.5
13. Swine fattening, 1st period	36.0	5.0	27.5		32.5	1:5.5
14. Swine fattening, 2nd period	31.0	4.0	24.0		28.0	1:6.0
15. Swine fattening, 3d period	23.5	2.7	17.5		20.2	1:6.5
Growing Cattle. Age months. — Average live weight per head.						
2 to 3 — 150 lbs.	22.0	4.0	13.8	2.0	19.8	1:4.7
3 to 6 — 300 lbs.	23.4	3.2	13.5	1.0	17.7	1:5.0
6 to 12 — 500 lbs.	24.0	2.5	13.5	0.6	16.6	1:6.0
12 to 18 — 700 lbs.	24.0	2.0	13.0	0.4	15.4	1:7.0
18 to 24 — 850 lbs.	24.0	1.6	12.0	0.3	13.9	1:8.0
Growing Sheep.						
5 to 6 — 56 lbs.	28.0	3.2	15.6	0.8	19.6	1:5.5
6 to 8 — 66 lbs.	25.0	2.7	13.3	0.6	16.6	1:5.5
8 to 11 — 76 lbs.	23.0	2.1	11.4	0.5	14.0	1:6.0
11 to 15 — 82 lbs.	22.5	1.7	10.9	0.4	13.0	1:7.0
15 to 20 — 86 lbs.	22.0	1.4	10.4	0.3	12.1	1:8.0
Growing Pigs (Breeding Stock).						
2 to 3 — 50 lbs.	42.0	7.6	28.0	1.0	36.6	1:4.0
3 to 5 — 100 lbs.	34.0	5.0	23.1	0.8	28.9	1:5.0
5 to 6 — 124 lbs.	31.5	3.7	21.3	0.4	25.4	1:6.0
6 to 8 — 170 lbs.	27.0	2.8	18.7	0.3	21.8	1:7.0
8 to 12 — 250 lbs.	21.0	2.1	15.3	0.2	17.6	1:7.5
Growing Pigs (Fattening).						
2 to 3 — 50 lbs.	44.0	7.6	28.0	1.0	36.6	1:4.0
3 to 5 — 100 lbs.	35.0	5.0	23.1	0.8	28.9	1:5.0
5 to 6 — 150 lbs.	33.0	4.3	22.3	0.6	27.2	1:5.5
6 to 8 — 200 lbs.	30.0	3.6	20.5	0.4	24.5	1:6.0
9 to 12 — 300 lbs.	26.0	3.0	18.3	0.3	21.6	1:6.4

TABLE IV.—Feeding Standards. (*Continued.*)

Per Head per Day.

		Total Dry Matter.	Nutrients.				Nutritive Ratio.
			Protein.	Carbo-Hydrates.	Fat.	Total.	
Growing Cattle.							
Age months.	Average live weight per head.						
2 to 3	150 lbs.	3.3	0.6	2.1	.30	3.0	1:4.7
3 to 6	300 lbs.	7.0	1.0	4.1	.30	5.4	1:5.0
6 to 12	500 lbs.	12.0	1.3	6.8	.30	8.4	1:6.0
12 to 18	700 lbs.	16.8	1.4	9.1	.28	10.8	1:7.0
18 to 24	850 lbs.	20.4	1.4	10.3	.26	11.0	1:8.0
Growing Sheep.							
5 to 6	56 lbs.	1.6	0.18	0.87	.05	1.10	1:5.5
6 to 8	60 lbs.	1.7	0.18	0.85	.04	1.07	1:5.5
8 to 11	76 lbs.	1.7	0.16	0.85	.04	1.05	1:6.0
11 to 15	82 lbs.	1.8	0.14	0.89	.03	1.06	1:7.0
15 to 20	86 lbs.	1.9	0.12	0.88	.03	1.03	1:8.0
Growing Pigs (Fattening).							
2 to 3	50 lbs.	2.1	0.38	1.50		1.88	1:4.0
3 to 5	100 lbs.	3.4	0.50	2.50		3.00	1:5.0
5 to 6	124 lbs.	3.9	0.54	2.96		3.50	1:5.5
6 to 8	170 lbs.	4.6	0.58	3.47		4.05	1:6.0
8 to 12	250 lbs.	5.2	0.62	4.05		4.67	1:6.5

Besides the necessary amount of nutrients, the food must have a certain bulk furnished by the coarse fodder, which helps digestion, and tends to keep the animal satisfied and healthy. The measure of the bulk is the amount of dry matter, or organic matter, in the ration, as shown by the figures 24 for the ration of a milch cow; of course, this may vary without any serious results. The kind of food a dairyman would give depends on what is the main crop or by-product in his section, how near he is to market, and the cost of the different concentrated foods at his command.

Grave errors may arise by following too closely the standards and rations set down by chemical research alone, without taking into account the local circumstances, and the individual needs of the animals, as well as the variation of the feeding-stuffs themselves; yet, without any knowledge of the composition of the substance fed, the farmer is not only in the dark as to the benefit to be derived from the food, but is also ignorant of the actual amount necessary; thus, at times, wasting considerable and valuable material.

RATIONS.

From the figures given in Table IV, rations can be calculated by having the analyses of the different foods before one. In order to facilitate matters in this direction, Table V has been made up from data given in Table II. It shows the total weight of dry matter, and amounts of digestible nutrients in different weights of feeding-stuffs. The use of this table is explained on page 31.

TABLE V.—Pounds of Dry Matter and Digestible Nutrients in Different Quantities of Fodders and Feedstuffs.

	Lbs.	Dry Matter.	Proteim.	Carbo-hydrates.	Fat.	Nutritive Ratio.
Green Fodders.						
Alfalfa	5	1.00	.19	.36	.03	1: 2.3
	10	2.00	.37	.73	.06	
Australian saltbush	5	1.18	.13	.46	.02	1: 3.9
	10	2.35	.25	.92	.03	
Barley	5	1.05	.10	.51	.02	1: 5.8
	10	2.10	.20	1.02	.04	
Corn	5	1.04	.05	.58	.02	1:12.5
	10	2.08	.10	1.16	.04	
Marsh ("Biston") grass	5	2.50	.13	1.22	.04	1:10.2
	10	5.00	.26	2.44	.09	
Oats	5	1.90	.13	.92	.05	1: 8.1
	10	3.80	.26	1.84	.10	
Peas and oats	5	.80	.09	.36	.01	1: 4.2
	10	1.60	.18	.72	.02	
Sorghum	5	1.03	.03	.61	.02	1:21.8
	10	2.06	.06	1.22	.04	
Silage.						
Barley	5	1.30	.09	.64	.04	1: 8.2
	10	2.60	.18	1.27	.09	
Clover, red	5	1.40	.10	.68	.05	1: 7.9
	10	2.80	.20	1.36	.10	
Corn	5	1.25	.06	.67	.03	1:11.7
	10	2.50	.13	1.35	.06	
Oat	5	1.40	.08	.74	.04	1:11.0
	10	2.80	.15	1.48	.09	
Orchard grass	5	1.15	.06	.53	.05	1:11.4
	10	2.30	.11	1.06	.10	
Roots, Beet pulp, etc.						
Beets, Mangels	5	.50	.06	.24	.005	1: 4.5
	10	1.00	.11	.47	.010	
Beets, Sugar	5	.80	.08	.60	.005	1: 7.6
	10	1.60	.16	1.20	.010	
Beet pulp, fresh	5	.50	.05	.37	.006	1: 8.2
	10	1.00	.09	.73	.011	
Beet pulp, silage	5	.56	.06	.39	.010	1: 6.8
	10	1.11	.12	.77	.020	
Pie melons	5	.47	.03	.17	.010	1: 5.4
	10	.95	.07	.33	.020	
Pumpkins	5	.50	.06	.20	.015	1: 4.0
	10	1.00	.12	.40	.030	
Hays.						
Alfalfa	5	4.45	.62	1.86	.08	1: 3.3
	6	5.34	.74	2.23	.09	
	7	6.23	.86	2.60	.11	
	8	7.12	.99	2.97	.12	
	9	8.01	1.11	3.34	.14	
	10	8.90	1.23	3.71	.16	
	13	11.57	1.60	4.83	.20	
	15	13.35	1.85	5.57	.24	
	18	16.02	2.22	6.68	.28	
Australian saltbush	5	4.65	.44	1.90	.06	
	6	5.58	.53	2.29	.07	
	7	6.51	.61	2.68	.08	
	8	7.44	.70	3.06	.10	

TABLE V.—POUNDS OF DRY MATTER AND DIGESTIBLE NUTRIENTS IN DIFFERENT QUANTITIES OF FODDERS AND FEEDSTUFFS. (*Continued.*)

	Lbs.	Dry Matter.	Protein.	Carbo-hydrates.	Fat.	Nutritive Ratio.
Australian saltbush .... (*Continued.*)	9	8.37	.79	3.44	.11	
	10	9.30	.88	3.82	.12	
	13	11.09	1.14	4.97	.16	
	15	13.95	1.32	5.72	.18	
	18	16.64	1.58	6.88	.22	
Barley	5	4.57	.29	2.16	.08	1: 8.1
	6	5.49	.35	2.59	.09	
	7	6.40	.40	3.02	.11	
	8	7.31	.46	3.45	.12	
	9	8.23	.52	3.88	.14	
	10	9.14	.58	4.31	.16	
	13	11.89	.75	5.60	.20	
	15	13.72	.86	6.47	.23	
	18	16.46	1.04	7.76	.28	
Bur clover	5	4.50	.37	2.06	.09	1: 6.2
	6	5.39	.44	2.47	.11	
	7	6.29	.51	2.88	.12	
	8	7.19	.58	3.30	.14	
	9	8.09	.65	3.71	.16	
	10	8.99	.73	4.12	.18	
	13	11.69	.94	5.36	.23	
	15	13.49	1.09	6.18	.26	
	18	16.18	1.31	7.42	.32	
Clover, red	5	4.25	.34	1.78	.09	
	6	5.10	.41	2.15	.10	
	7	5.95	.48	2.51	.12	
	8	6.80	.54	2.86	.14	
	9	7.65	.61	3.22	.15	
	10	8.50	.68	3.58	.17	
	13	11.05	.88	4.65	.22	
	15	12.75	1.02	5.36	.26	
	18	15.30	1.22	6.44	.31	
Oat	5	4.50	.22	2.19	.07	1:10.5
	6	5.40	.27	2.62	.09	
	7	6.30	.31	3.06	.10	
	8	7.20	.36	3.50	.12	
	9	8.10	.40	3.94	.13	
	10	9.00	.45	4.37	.15	
	13	11.70	.58	5.69	.19	
	15	13.50	.67	6.56	.22	
	18	16.20	.80	7.87	.26	
Wheat	5	4.56	.18	2.30	.05	1:13.2
	6	5.47	.21	2.76	.07	
	7	6.38	.25	3.22	.08	
	8	7.29	.29	3.68	.09	
	9	8.20	.32	4.14	.10	
	10	9.12	.36	4.61	.11	
	13	11.86	.47	5.99	.14	
	15	13.78	.54	6.91	.16	
	18	16.41	.64	8.30	.20	

TABLE V.—POUNDS OF DRY MATTER AND DIGESTIBLE NUTRIENTS IN DIFFERENT QUANTITIES OF FODDERS AND FEEDSTUFFS. (*Continued.*)

	Lbs.	Dry Matter.	Protein.	Carbo-hydrates.	Fat.	Nutritive Ratio.
Mixed	5	4.62	.22	2.36	.08	1:11.5
	6	5.54	.26	2.84	.10	
	7	6.46	.31	3.31	.11	
	8	7.39	.35	3.78	.13	
	9	8.31	.39	4.25	.15	
	10	9.24	.44	4.73	.17	
	13	12.00	.58	6.15	.21	
	15	13.85	.660	7.09	.250	
	18	16.62	.790	8.51	.300	
Straw, average	1	.89	.008	.39	.006	1: 5.0
	2	1.78	.016	.77	.012	
	3	2.67	.024	1.16	.018	
	4	3.56	.032	1.55	.024	
	5	4.45	.040	1.94	.030	
	7	6.23	.056	2.71	.048	
	9	8.01	.072	3.48	.054	
Gourd Vines.						
"Mock Orange"	5	4.30	.26	1.88	.06	1: 7.9
	6	5.16	.31	2.25	.08	
	7	6.02	.36	2.63	.09	
	8	6.88	.41	3.00	.10	
	9	7.74	.46	3.38	.11	
	10	8.60	.51	3.75	.13	
	13	11.18	.67	4.88	.16	
	15	12.90	.77	5.63	.19	
	18	15.48	.92	6.75	.23	
Grain and Millstuffs.						
Barley, rolled	1	.90	.10	.63	.02	1: 7.1
	2	1.80	.19	1.27	.04	
	3	2.70	.29	1.90	.06	
	4	3.60	.38	2.54	.08	
	5	4.50	.48	3.17	.10	
	7	6.30	.58	4.44	.14	
Oats	1	.89	.09	.47	.04	1: 6.2
	2	1.68	.18	.95	.08	
	3	2.67	.28	1.42	.13	
	4	3.56	.37	1.89	.17	
	5	4.45	.46	2.36	.21	
	7	6.23	.64	3.31	.29	
Wheat, whole	1	.89	.09	.50	.01	1: 5.6
	2	1.77	.19	1.00	.03	
	3	2.66	.28	1.50	.04	
	4	3.54	.38	2.00	.06	
	5	4.43	.47	2.50	.07	
	7	6.27	.65	3.50	.09	
Wheat, screenings	1	.89	.08	.49	.02	1: 6.6
	2	1.78	.16	.97	.04	
	3	2.66	.24	1.46	.05	
	4	3.55	.32	1.95	.07	
	5	4.44	.40	2.44	.09	
	7	6.22	.56	3.41	.13	

TABLE V.—POUNDS OF DRY MATTER AND DIGESTIBLE NUTRIENTS IN DIFFERENT QUANTITIES OF FODDERS AND FEEDSTUFFS. (*Continued.*)

	Lbs.	Dry Matter.	Protein.	Carbo-hydrates.	Fat.	Nutritive Ratio.
Wheat, bran	1	.88	.11	.42	.03	1: 4.3
	2	1.76	.22	.84	.05	
	3	2.65	.34	1.27	.08	
	4	3.53	.45	1.69	.10	
	5	4.41	.56	2.11	.13	
	7	6.18	.79	2.95	.18	
Wheat, Middlings	1	.88	.12	.53	.04	1: 5.1
	2	1.76	.24	1.07	.08	
	3	2.65	.37	1.60	.11	
	4	3.53	.49	2.14	.15	
	5	4.41	.61	2.67	.19	
	7	6.18	.85	3.74	.27	
Wheat, Shorts	1	.90	.12	.48	.03	1: 4.5
	2	1.80	.24	.96	.06	
	3	2.70	.36	1.44	.09	
	4	3.60	.49	1.92	.11	
	5	4.50	.61	2.40	.14	
	7	6.30	.85	3.35	.20	
Mixed feed	1	.89	.10	.47	.03	1: 5.6
	2	1.79	.19	.95	.06	
	3	2.68	.29	1.42	.09	
	4	3.58	.38	1.90	.12	
	5	4.47	.48	2.37	.15	
	7	6.16	.67	2.84	.21	
Corn meal	1	.88	.06	.66	.03	1:11.6
	2	17.6	.13	1.33	.07	
	3	2.64	.19	1.99	.10	
	4	3.52	.26	2.65	.13	
	5	4.40	.32	3.31	.17	
	7	6.16	.45	4.64	.24	
Oil-Cake Meals.						
Linseed (new process)	½	.45	.13	.19	.03	1: 2.
	1	.89	.26	.38	.07	
	2	1.78	.52	.77	.13	
	3	2.67	.78	1.15	.20	
	4	3.56	1.04	1.54	.26	
	5	4.45	1.30	1.92	.33	
Cocoanut	½	.43	.08	.21	.05	
	1	.86	.16	.42	.10	
	2	1.72	.33	.85	.20	
	3	2.58	.49	1.27	.30	
	4	3.44	.66	1.70	.40	
	5	4.30	.82	2.12	.50	
Cottonseed	½	.45	.21	.08	.06	1: 1.
	1	.90	.41	.15	.11	
	2	1.80	.82	.31	.22	
	3	2.70	1.23	.46	.33	
	4	3.60	1.64	.62	.44	
	5	4.50	2.05	.77	.55	

FEEDING COWS AND STEERS.

The large and rapidly increasing dairy interests of this State render the feeding of milch cows a very important subject. No animal responds more gratefully or profitably to careful feeding, and there is none more willing to consume coarse foods than she. This is due to the peculiar construction of her digestive system, which, like that of other ruminants, includes four stomachs, three of which enable her to prepare for digestion and assimilation of nutriment from food entirely unsuited to non-ruminants. But because she can utilize this roughage does not mean that this kind of food is sufficient for her wants.

As Dr. Allen says: "The cow requires not only materials for her maintenance, but must also have protein, fat, and carbohydrates to make milk from. The milk contains water, fat, protein (casein or curd), sugar, and ash, and these are all made from the constituents of the food. If insufficient protein, fat, and carbohydrates are contained in the food given her, the cow supplies the deficiency for a time by drawing on her own body, and gradually shrinks in quantity and quality of milk, or both. The stingy feeder cheats himself as well as the cow. She suffers from hunger, although her belly is full of swale hay, but she also becomes poor and does not yield the milk and butter she should. Her milk glands are a wonderful machine, but they cannot make milk casein out of carbohydrates or coarse, unappetizing, indigestible swale hay or sawdust, any more than the farmer himself can make butter from skim milk. She must not only have a generous supply of good food, but it must contain a sufficient amount of the nutrients needed for making milk. Until this fact is understood and appreciated, successful, profitable dairying is out of the question. The cow must be regarded as a living machine. She takes the raw materials given her in the form of food, and works them over into milk. If the supply of proper materials is small, the output will be small. The cow that will not repay generous feeding should be disposed of at once, and one bought that will. There are certain inbred *characteristics* which even liberal feeding cannot overcome."

How to Use Tables in Compounding Rations.—Suppose a dairyman were feeding dairy cows and wished to make up a ration in accordance with standard 8, viz.: 24 pounds dry matter, 2.5 pounds digestible protein, 12.5 pounds digestible carbohydrates with .4 pounds of fat, from oat hay, bran, middlings, and linseed meal. A general principle, where grain is fed to cows, is to make up the ration in such a way as to have about two-thirds of the total dry matter supplied by the coarse fodder and the remaining one-third by the concentrated food. In this case, then, the dairyman would need about 18 pounds of hay, which by the table is found to contain 16.2 pounds of dry matter, or about two-thirds of 24, the total amount required by a 1000-pound cow. Eight pounds of dry matter is then left to be furnished by the grain, and about nine pounds will be needed, since nearly all the grain contains approximately ninety per cent. of dry matter. For a continuous diet it is not well to feed more than two pounds daily per head of linseed meal, and it will therefore require this amount for the ration. We will suppose that the remaining seven pounds may be divided so as to use three pounds of bran and four pounds of middlings. Turning to Table V for the several quantities as above mentioned of the different foods, the following ration can be compounded:

Lbs.		Dry Matter.	Protein.	Carbohydrates.	Fat.
18	Oat hay	16.20	.80	7.87	.26
3	Bran	2.65	.34	1.27	.08
4	Middlings	3.53	.49	2.14	.15
2	Linseed meal	1.78	.52	.77	.13
		24.16	2.15	11.95	.62

Nutritive ratio, 1: 6.25.

The ration is lacking mainly in protein, which makes the nutritive ratio wider than is called for by the standard. The total amount of dry matter is high enough, and thus any change cannot be made by adding other foods, but must be made by substituting some food containing a large percentage of protein for one of the foods now used. Cottonseed meal may be used for this substitution, and one pound will suffice in place of one pound of middlings. The altered ration would then be:

Lbs.		Dry Matter.	Protein.	Carbohydrates.	Fat.
18	Oat hay	16.20	.80	7.87	.26
3	Bran	2.65	.34	1.27	.08
3	Middlings	2.65	.37	1.60	.11
2	Linseed meal	1.78	.52	.77	.13
1	Cottonseed meal	.90	.41	.15	.11
		24.18	2.44	11.66	.69

Nutritive ratio, 1: 5.4.

This ration corresponds very closely to the standard, and would undoubtedly give better results than the first one. The pound of cottonseed meal costs much more than one pound of middlings, but, considering the amount of protein furnished, the cottonseed meal is the cheaper.

As another illustration; a dairyman writes that he is feeding 9 pounds of alfalfa hay, 50 pounds of corn silage and 5 pounds of wheat bran. Taking the sum of the various nutrients from Table V as before, we find the ration to contain the following:

Lbs.		Dry Matter.	Protein.	Carbohydrates.	Fat.
9	Alfalfa hay	8.01	1.11	3.34	.14
50	Corn silage	12.50	.64	6.74	.28
5	Wheat bran	4.41	.56	2.11	.13
		24.92	2.31	12.19	.55

Nutritive ratio, 1:5.8. Cost, 100 cows per day, $12.85.

With the exception of a shortage in protein, this is a very good ration. It may be benefited in this respect by feeding less silage and more bran, when a ration somewhat as follows is the result:

Lbs.		Dry Matter.	Protein.	Carbohydrates.	Fat.
9	Alfalfa hay	8.01	1.11	3.34	.14
35	Corn silage	8.75	.44	4.72	.20
9	Wheat bran	7.95	1.02	3.81	.24
		24.71	2.57	11.87	.58

Nutritive ratio, 1:5.1. Cost, 100 cows per day, $14.75.

This ration is better than the original one from the standpoint of the protein and nutritive ratio. It also has the proportion of one-third of the total dry matter made up of concentrated foods as mentioned in the first illustration. But it is more expensive than the original by nearly two dollars per day for 100 cows. The principle referred to, in regard to making two-thirds of the dry matter of the ration come from the coarse fodder and one-third from the concentrates, is an Eastern feeding practice. It is partly necessary because the concentrates must be used to supply the requisite amount of protein, since most of the Eastern coarse fodders do not contain this element in so large a proportion as alfalfa. With alfalfa, as shown elsewhere, it is possible to provide enough protein without using any other food. Taking the three foods in question, we may make another ration, depending more largely upon the alfalfa for protein, as follows:

Lbs.		Dry Matter.	Protein.	Carbohydrates.	Fat.
12	Alfalfa hay	10.68	1.48	4.46	.18
40	Corn silage	10.00	.50	5.39	.22
4	Wheat bran	3.53	.45	1.69	.10
		24.21	2.43	11.54	.50

Nutritive ratio, 1:5.2. Cost, 100 cows, per day, $12.20.

This is the cheapest of all three rations, and is as good as the second as regards the total and proportion of digestible nutrients. It contains less bran than either of the others, but is sufficient to make a good palatable ration. The calculation of the cost of the ration is based on prices as given in Table III on page 14.

Additional matter relating to the feeding of milch cows is given in the body of this Bulletin.

Feeding Alfalfa.—Bulletin No. 148 of the New Jersey Experiment Station reports experiment an comparing alfalfa protein with purchased protein for dairy cows. They fed four cows during a period of two months on two separate rations, one made up of corn silage, alfalfa hay, mixed hay, and cotton-seed meal; the other of corn silage, mixed hay, wheat bran, dried brewer's grains, and cotton-seed meal. The results of the experiment are summarized in the table showing the food consumed, the yield of milk and butter per head daily, and the cost for food to produce 100 pounds of milk and 1 pound of butter with each ration.

		Food consumed per cow per day.							Yield.		Cost to produce.	
	No. of days.	Corn silage.	Alfalfa hay.	Mixed hay.	Wheat bran.	Dried brewers' grains.	Cottonseed meal.	Cost of ration. Cents.	Milk, pounds.	Butter, pounds.	100 pounds milk, cents.	1 pound butter, cents.
Ration 1..	60	35	11	6	....	....	2	12.08	20.8	.87	58.0	12.0
Ration 2..	60	35	....	6	4	4	2	15.38	21.8	.92	70.7	14.3

This experiment shows that while the ration in which the protein was supplied by purchased grain produced slightly more milk and butter than the alfalfa ration, still the latter produced milk at 12.7 cents per 100 pounds and butter at 2.3 cents less per pound than the former. It will be noticed that two pounds of cotton-seed meal were in each ration, and that there was no comparison of rations wholly without grain.

The usual feeding practice in alfalfa districts is to depend entirely upon alfalfa pasture and alfalfa hay for cattle feed, except for the vexing foxtail, which comes up every spring. That this is a cheap method of feeding cannot be denied. That it would be cheaper to supplement the alfalfa with other feeds, either grown at home or purchased, is not yet proven to the satisfaction of all. The experience of a few dairymen has shown that some straw judiciously fed with alfalfa has lessened the cost of the ration and added to its palatability. The few also who have fed corn silage report most satisfactory results. The most simple rule of animal feeding is broken when a cow is required to subsist on alfalfa alone, or any other single food, for no animal can be expected to do its *best* when confined to a single food. The question then comes, will the cow do so much better on two or three different foods to pay for buying or raising the extra ones? On many ranches food material goes to waste, or is burned; such as straw, which if well preserved would be relished by the cow along with alfalfa. And in every dairy section in California corn can be grown in sufficient quantity to furnish silage to supplement dry pasture and add to the cow's change of food.

A few illustrative rations will show how the cost of feeding varies between feeding much or little grain, or little or much alfalfa. In calculating the cost of the following rations the same schedule of prices is used as shown in Table III. The rations are each made up with a view to secure as nearly a standard ration as possible with the foods used, and to have them all nearly the same in total dry matter. The various rations follow:—

RATION 1

10 lbs alfalfa hay
8 lbs barley hay
3 lbs wheat bran
3 lbs crushed barley
2 lbs corn meal
Nutritive ratio, 1:5.2
Cost 100 cows per day $15.30

RATION 2

13 lbs alfalfa hay
10 lbs barley hay
2 lbs wheat bran
2 lbs crushed barley
Nutritive ratio 1:5
Cost 100 cows per day $13.10

RATION 3

13 lbs alfalfa hay
13 lbs barley hay
Nutritive ratio 1:4.8
Cost 100 cows per day $11.05

RATION 4

20 lbs alfalfa hay
8 lbs straw (average)
Nutritive ratio 1:4.5
Cost 100 cows per day $9.20

RATION 5

27 lbs alfalfa hay
Nutritive ratio 1:3.3
Cost 100 cows per day $10.80

Feeding Beet Pulp.—We have no detailed experiment to report for this State concerning the value of beet pulp as a stock food, nor showing how it should best be fed. We have, however, the record of milk production from a small herd of cows which were fed beet pulp for about ten weeks. And through the kindness of several of the leading stockmen of the State we have secured their experience in feeding it and are able to present it here. It is interesting to note that the results obtained from feeding the pulp in this State agree with European experience.

The herd of cows mentioned above were owned in Berkeley by Mr. W. B. Barber, who kept the milk record and weighed the beet pulp which each cow consumed. The cows were mostly Shorthorn foundation, with some infusion of Jersey blood. All but "Jersey" dropped their calves in July, 1900, and she in April. Owing to various circumstances, it was not possible to keep an accurate record of the weight of hay consumed, and thus the amount required by each cow can be given only approximately. When no beet pulp was fed, the cows ate an average of about 20 pounds of hay per head daily in addition to 8 pounds of grain. When eating beet pulp the daily consumption of hay varied from 6 to 16 pounds, depending upon the amount of beet pulp in the ration and the size of the cow. The hay was a fair quality of oat with a slight ad-mixture of bur clover. The grain consisted of 8 pounds per head daily of a mixture of 3 parts of wheat bran and 2 parts of cocoanut-cake meal given dry in two feeds. Calculating this ration on a basis of 8 pounds of grain, 9 pounds of hay, and 60 pounds of beet pulp, it had a nutritive ratio of 1:6.2 and contained 21.75 pounds of dry matter.

The sugar-beet pulp was donated to the Station by the Alameda Sugar Company of Alvarado, through the kindness of the superintendent of the company, Mr. E. W. Burr. Transportation was furnished to Berkeley free on the first car-load of pulp, and at half rates on the second car-load by the Southern Pacific Railroad Company.

The record of milk production, as given in the table below, began on September 5, 1900. From that date until October 10th the feed of the cows was hay and grain, as mentioned above. On the latter date, which was the sixth week in the table, beet pulp was given to all the cows in small quantities. This amount was so irregular, owing to the freshness of the pulp and the dislike of most of the cows for it in that condition, that a full ration of pulp was not secured until the seventh week. For the succeeding three weeks hay was fed once a day and beet pulp once, in amounts varying from 40 to 65 pounds per head, according to the size and appetite of the animal. Beginning with the tenth week, the hay, grain, and beet pulp were fed together, each in two daily feeds. With some of the cows the quantity of pulp given was increased 5 pounds per day until they received 80 pounds each, and with others decreased until they received only 20 pounds each. After a time the order was reversed; the rations for those receiving the large amounts were decreased, and for those receiving small amounts increased until two were receiving 90 pounds each daily. The period of feeding beet pulp closed during the sixteenth week, after which the cows received the former ration of hay and grain. During the whole period the cows had the range of several small fields, but the amount of food obtained there was of little practical value.

The beet pulp seemed to impart no foreign or disagreeable flavor to the milk. The milk was delivered daily to customers in Berkeley, and no complaint was made as to its quality. The effect of the pulp upon the flow of milk was on the whole beneficial. Most of the cows were decreasing in yield up to the time when we began to feed beet pulp, after which all increased in quantity, and continued to hold out well until the beet pulp was exhausted, when there was a noticeable decrease. In regard to the influence of beet pulp upon the percentage of fat in the milk, the records do not show any material effect either in raising or lowering the proportion of fat. The record of milk and fat production is given below, for the study of all who are interested therein.

The milk record was kept as follows:—Each cow's milk was weighed at every milking as soon as drawn, and the weight recorded on a sheet provided for the purpose. At the same time about one-half ounce of the milk was taken as a sample to test for fat, and placed in a bottle containing milk preservative. These composite samples were tested for fat once a week by the Babcock test. In the record, then, we have the weight of milk for each week, the average weekly per cent. of fat, and the pounds of fat produced each week. This record is given in the table below, together with the quantity of beet pulp consumed by each cow per week.

TABLE VI.—INDIVIDUAL WEEKLY RECORD OF MILK AND FAT PRODUCED AND OF BEET PULP CONSUMED.

	NORMAN. JERSEY—SHORTHORN. Age 6 years.				LINE BACK. ARYSHIRE—SHORTHORN. Age 5 years.			
No. of Weeks.	Milk, Pounds.	Fat, Per cent.	Fat, Pounds.	Beet Pulp Pounds.	Milk, Pounds.	Fat, Per cent.	Fat, Pounds.	Beet Pulp Pounds.
1	156.3	4.5	7.03	....	174.9	3.4	5.95	....
2	148.2	4.2	6.22	....	183.4	3.3	6.05	....
3	154.8	3.8	5.88	....	185.4	3.5	6.49	....
4	148.1	4.2	6.22	....	182.3	3.4	6.30	....
5	138.8	4.4	6.11	....	172.1	3.6	6.20	....
6	139.9	4.6	6.44	....	165.5	3.6	5.96	....
7	154.4	4.4	6.79	365	171.7	4.2	7.21	355
8	158.4	4.4	6.97	385	169.6	3.6	6.11	455
9	142.9	4.4	6.29	385	174.7	3.7	6.46	435
10	138.2	4.1	5.67	485	185.1	3.7	6.85	545
11	128.6	4.2	5.40	560	189.1	3.8	7.19	560
12	144.6	5.0	7.23	555	170.2	4.1	6.98	555
13	147.2	4.8	7.07	385	183.4	3.9	7.15	385
14	137.1	4.6	6.31	170	163.5	3.8	6.21	170
15	141.1	4.5	6.35	140	175.0	3.7	6.48	140
16	127.9	4.5	5.76	40	173.8	3.8	6.60	40
17	123.5	5.0	6.18	....	166.1	4.1	6.81	....
18	122.9	5.2	6.39	....	167.9	4.1	6.88	....
19	121.1	5.2	6.30	....	156.3	4.1	6.41	....

TABLE VI.—Individual Weekly Record of Milk and Fat Produced and of Beet Pulp Consumed. (*Continued.*)

	Strube. Jersey—Shorthorn. Age 6 years.				Jersey. High Grade Jersey. Age 10 years.			
No. of Weeks.	Milk, Pounds.	Fat, Per cent.	Fat, Pounds.	Beet Pulp Pounds.	Milk, Pounds.	Fat, Per cent.	Fat, Pounds.	Beet Pulp Pounds.
1	176.5	3.7	6.63	....	121.1	6.0	7.27	....
2	177.4	3.6	6.39	....	120.7	5.6	6.76	....
3	175.7	3.4	5.97	....	125.8	5.1	6.42	....
4	162.0	4.2	6.80	....	119.6	5.6	6.70	....
5	144.4	3.8	5.49	....	118.9	5.6	6.66	....
6	131.1	4.3	5.64	....	123.4	5.6	6.91	....
7	141.7	3.9	5.53	295	129.1	5.8	7.49	380
8	140.0	4.0	5.60	325	108.7	6.0	6.52	350
9	144.9	3.9	5.65	335	114.6	5.5	6.30	420
10	140.4	3.4	4.77	485	110.2	5.5	6.06	530
11	156.3	4.1	6.41	560	117.1	5.5	6.44	560
12	145.4	4.1	5.96	555	109.2	4.8	5.24	555
13	142.4	4.1	6.84	385	104.0	5.2	5.41	385
14	125.9	4.6	5.79	170	98.6	5.6	5.52	170
15	128.9	4.1	5.28	140	105.2	5.5	5.79	140
16	129.9	3.9	5.07	40	89.9	5.8	5.21	40
17	123.2	4.3	5.30	....	90.9	6.0	5.45	....
18	117.0	4.3	5.03	....	89.9	6.5	5.84	......
19	111.9	4.1	4.59	....	84.6	6.4	5.41	....

TABLE VI.—Individual Weekly Record of Milk and Fat Produced and of Beet Pulp Consumed. (*Continued.*)

	Irene. Grade Shorthorn. Age 6 years.				Sarah. Grade Shorthorn. Age 6 years.			
No. of Weeks.	Milk, Pounds.	Fat, Per cent.	Fat, Pounds.	Beet Pulp Pounds.	Milk, Pounds.	Fat, Per cent.	Fat, Pounds.	Beet Pulp Pounds.
1	186.0	3.6	6.70	......	149.6	3.6	5.39	......
2	175.0	3.4	5.95	......	147.0	3.5	5.15	......
3	167.0	3.6	6.01	......	145.5	3.2	5.66	......
4	172.4	4.0	6.80	......	130.6	3.6	4.70	......
5	166.8	3.2	5.34	......	*99.3	3.6	3.57	.....
6	156.4	4.0	6.26	......	115.4	3.8	4.38	......
7	180.8	3.6	6.51	295	125.5	3.8	4.77	200
8	176.6	3.7	6.53	315	125.4	4.2	5.27	350
9	186.2	3.6	6.70	340	130.0	3.6	4.68	350
10	167.2	3.1	5.18	215	110.0	3.5	3.85	215
11	163.0	3.7	6.03	140	114.9	4.1	4.70	140
12	163.4	3.4	5.56	145	112.6	3.7	4.17	145
13	177.2	3.6	6.38	315	119.9	3.6	4.32	315
14	186.0	3.6	6.70	530	132.6	3.8	5.04	530
15	194.4	3.4	6.61	560	141.4	3.4	4.81	560
16	175.9	3.6	6.33	160	119.5	3.7	4.42	160
17	153.7	3.8	5.84	.....	104.7	4.0	4.19	......
18	156.3	3.7	5.78	......	107.0	4.1	4.39	.....
19	144.6	3.8	5.49	....	98.5	4.2	4.14	......

* Sick.

TABLE VI.—Individual Weekly Record of Milk and Fat Produced and of Beet Pulp Consumed. (*Continued.*)

	KEOHAN. Grade Shorthorn. Age 8 years.				GEORGIA. Grade Shorthorn. Age 6 years.			
No. of Weeks.	Milk, Pounds.	Fat, Per cent.	Fat, Pounds.	Beet Pulp Pounds.	Milk, Pounds.	Fat, Per cent.	Fat, Pounds.	Beet Pulp Pounds.
1	127.4	4.4	5.60	......	165.6	3.6	5.96	......
2	112.8	4.6	5.19	......	169.4	3.8	6.44	......
3	121.3	3.6	4.37	......	168.0	3.6	6.05	......
4	102.0	4.2	4.28	......	152.5	3.7	5.64	......
5	103.8	4.5	4.67	......	147.9	3.2	4.73	......
6	107.7	4.7	5.06	.....	145.3	4.0	5.81	......
7	115.0	4.3	4.95	385	164.0	3.8	6.23	390
8	110.6	4.4	4.87	425	163.0	3.9	6.36	455
9	115.3	4.4	5.07	420	172.6	3.8	6.56	440
10	112.3	3.9	4.38	280	150.2	3.9	5.86	230
11	101.8	4.5	4.58	140	143.3	4.1	5.88	140
12	95.6	4.5	4.30	145	140.4	4.4	6.18	145
13	96.3	4.6	4.43	315	141.1	4.4	6.21	315
14	111.4	3.9	4.34	550	162.6	4.1	6.67	550
15	109.1	3.7	4.04	630	173.9	3.7	6.43	630
16	95.3	3.9	3.72	180	144.7	3.7	5.35	180
17	80.7	4.8	3.87	......	120.1	4.0	4.80	......
18	80.9	5.0	4.05	......	127.0	4.2	5.33	......
19	81.3	4.8	3.90	.....	124.3	4.2	5.22	.....

California Experience in Feeding Beet-pulp.—During the past year we submitted several questions to some of the leading stockmen of this State with a view to gathering their experience in feeding sugar-beet pulp. The parties who have replied are: Messrs. Henry Miller, John L. Koster, John H. Wise, W. Mayo Newhall, all of San Francisco; Thomas H. Silsbee, Point Conception; Fred D. Wiegman, Alvarado, and Messrs. Vail and Gates, Los Angeles. The questions asked and the answers of the different parties are here quoted.

Feeding Beef Cattle. 1.—How much pulp do you feed daily per head?

Mr. Koster.—90 to 100 pounds.

Mr. Wiegman.—About 100 pounds.

Mr. Silsbee.—An average of 112 pounds of siloed pulp.

Messrs. Vail and Gates.—A four-year old steer will eat about 80 pounds of siloed pulp.

Mr. Miller.—About 100 pounds of fresh or 60 pounds of fermented pulp.

Mr. Newhall.—The daily average consumed per animal will vary from 80 to 100 pounds. For animals of 1,000 to 1,100 pounds weight the former quantity should suffice.

2.—Do you feed hay or grain with the pulp, and if so, how much and of what kind?

Mr. Koster.—10 to 15 pounds uncut hay and 2½ to 5 pounds finely rolled barley—quantity regulated bv condition of the cattle and the state of the weather. In cold weather a greater proportion of hay and barley than in warm weather.

Mr. Wiegman.—About 5 pounds of oat hay and 3 pounds of mixed "chop" feed.

Mr. Silsbee.—10 to 12 pounds of lima bean-straw.

Messrs. Vail and Gates.—About six pounds of barley hay and straw. Have generally fed about 8 pounds of ground corn for the last forty days of feeding. When we feed cotton-seed meal we give about 3 pounds per day.

Mr. Miller.—About ten pounds of either alfalfa hay, grain hay or straw chopped and mixed with grain, usually ground barley, though sometimes cracked wheat. The quantity of grain varies with the quality of the hay or straw. The better the hay the less grain used.

Mr. Newhall.—We fed rolled barley and chevalier barley-straw. The best result is obtained when the grain is crushed as finely as possible, the finer the better. Mill sweepings of grains, flour, corn, etc., are excellent. At the commencement of feeding the cattle a half pound of grain per day should be used and a full ration would be 8 to 10 pounds daily. We were from necessity forced to use chevalier barley-straw as a roughage, and from that experience, together with observation in the use of hay by others, I am decidedly of the opinion that such straw is far better; in fact, at the same price I would prefer the straw. In this connection I would beg to say that baled straw would have a market value of say $3.00 per ton, as against a value for baled hay of about $10.00 per ton.

3.—How long is the period during which you feed beet pulp continuously?

Mr. Koster.—During the winter months, covering a period of 90 to 120 days.

Mr. Wiegman.—Until fat; usually four to four and a half months.

Mr. Silsbee.—90 days.

Messrs. Vale and Gates.—From 100 to 120 days.

Mr. Miller.—About four months.

Mr. Newhall.—We fed during the season of 1900, 8000 head of beef cattle covering a period of about four months; but the average time in which various lots were finished and sold was about two months. The usual period in this State of those who have fed is from three to four months, but this would depend upon and materially vary according to the temperment and to the condition of the animal at the commencement of the feeding period.

4.—What is the effect of beet pulp in the production of meat?

Mr. Koster.—On good thrifty beef cattle the production of meat was superior to that of northern alfalfa-fed cattle. The meat was of fine flavor, good color, marbleized, and killing very white as to fat.

Mr. Wiegman.—Makes white fat and tender and juicy meat.

Mr. Silsbee.—Horned cattle gained an average of 1½ pounds per day, and dehorned cattle about two pounds per day.

Messrs. Vail and Gates.—Fattens rapidly after the first 30 days' feed. Makes a fine quality of beef, the tallow being very white.

Mr. Miller.—Has been more remunerative as a food for meat than for milk.

Mr. Newhall.—Pulp fed with grain and hay or straw, produces a very well marbled condition of the meat; a decided effect of the pulp is the fine white color given to the carcass when dressed. I am of the opinion that, coupled with the result of confinement, the muscles and sinews of the animals are softened and less in evidence upon the block, thus making a much more acceptable article of meat for sale and use.

5.—How much per ton do you consider you can afford to pay for pulp delivered at your ranch?

Mr. Koster.—This would depend upon the value of other food materials.

Mr. Wiegman.—One dollar per ton.

Mr. Silsbee.—Depends on the scarcity of cattle feed and the price of beef.

Messrs. Vail and Gates.—After being siloed and well drained, 75 cents per ton. Have never fed at ranch; have always shipped cattle to factory.

Mr. Miller.—It depends upon the price of beef. At present prices we can afford to pay 50 cents per ton for fresh and 75 cents per ton for fermented pulp.

Mr. Newhall.—It would be difficult to economically feed pulp away from the factory, as transportation and handling of pulp is quite expensive. Factories sell pulp at from 10 to 25 cents per ton; the former price has been the custom when taken away from the factory, the latter when conveniences and facilities for feeding cattle have been furnished at or near the factories. I doubt any profitable use for beef-feeding at over 25 cents per ton for pulp. At this price, and the usual value of grain and hay or straw, it will cost from $9.00 to $12.00 per head to put the animal into good marketable condition. At the present and usual price of purchase and sale of cattle in California these figures ($9.00 to $12.00) are the full margin of profit when fattened on grass on the ranges and without any extra cost of feeding. I am of the opinion that under ordinary conditions in our State, except by small farmers, pulp, or in fact any feeding, cannot be profitably carried on; but pulp is a most excellent thing to have in this State to fall back on in case of emergencies, like dry years and seasons when cattle do not properly fatten on the ranges. I believe, however, that small farmers who do their own work can purchase cattle, fatten them, and sell to a profit that would be satisfactory to them, especially as lots can be turned off every three or four months. This would be especially true of farmers in the localities where sugar beets are raised, and a long start made by feeding beet tops, and which would require but litle time, say one month, for finishing on pulp with grain and hay.

Feeding Dairy Cattle.—Mr. Koster and Mr. Wiegman are the only ones reporting any extensive practice of feeding beet pulp for milk. Mr. Koster writes that he considers 20 to 25 pounds per head daily a sufficient amount of pulp for a dairy cow. With the pulp he feeds from 25 to 30 pounds of uncut hay and five pounds of middlings per day. He says there was no noticeable odor in the milk when feeding pulp, but that "too much pulp had the tendency to lessen the yield of milk as well as to impoverish it."

Mr. Wiegman replies that he considers 80 pounds of pulp per head daily a maximum amount to be fed with profit, and 20 to 25 pounds as a minimum. His usual feed is about 80 pounds per day. With the pulp he feeds 6 to 7 pounds of hay (oat preferred) and 6 pounds of mixed "chop" feed. He has pulp continually and feeds it throughout the year. If the cows are fed wholly on pulp the milk seems to become poorer. No foreign odor or flavor is noticeable in the milk, except occasionally when the beet-pulp is fresh, none at all when feeding siloed pulp.

FEEDING OTHER STOCK.—Mr. Koster reports having fed beet pulp to sheep with good success, and adds: "In feeding pulp much depends upon the age and condition of the pulp, and upon the condition of the stock and suitable grounds for feeding."

Mr. Miller reports that they have fed pulp to sheep with satisfactory results, but do not consider it suitable to other animals than cattle.

Mr. Wise fed beet pulp to sheep only. He says: "Our experience was not very favorable. I am perfectly satisfied that beet-pulp alone will not fatten stock of any kind. We had to buy other food to mix with it, otherwise our sheep would have fallen off instead of gaining flesh."

ADDITIONAL COMMENTS.—The experience given above shows clearly that beet-pulp should not be depended upon as the sole diet either for producing milk or meat, the chief reason being that it does not adequately nourish the animal. When fed in connection with other and dry feed it not only serves to keep the digestion in a healthful condition, but adds materially to the store of actual food substance. The amount of pulp which can be fed profitably is reported by all who feed for meat, as all the animals will readily consume in addition to the portion of hay or straw and grain, as already mentioned. In the case of the profitable quantity to feed for milk production there seems to be a wide difference of opinion. It may be that 25 or 30 pounds per day of pulp will induce as large a flow of milk as 80 pounds per day when the rest of the feed is dry; the notion being that the lesser quantity gives the cow all the succulent food and change of diet which she really requires for the best production. Where the pulp must be hauled a long distance and the cost of transportation is therefore great, it would undoubtedly be unwise to feed it in larger amounts than would give the necessary succulence to the ration, and 25 pounds is probably sufficient for this purpose. But where the dairy is situated adjacent to the sugar factory, as at Alvarado, it might pay to feed the pulp in much larger quantities.

Some further notes in regard to feeding beef cattle are worthy of consideration. Mr. Newhall writes: "I would further assume to say that, in my opinion, the climate of our State is not the most suitable for feeding purposes, especially in winter. I would particularly direct caution in undertaking to feed cattle during our winter months in small enclosures, where mud, exposure to dampness and winds have had a decidedly detrimental effect." In this connection Mr. Koster says: "When cattle are once started on pulp feed, particularly when fed to be fattened foı beef, it is advisable to continue them at that until fully fat and then to slaughter them. If cattle have been on this feed for a season, it is highly inadvisable, if they have reached the desired stage, to take them on green pasture, as this affects them seriously. Proper feeding grounds should be selected where the cattle can be sheltered during stormy weather."

LIST OF BEET SUGAR FACTORIES IN CALIFORNIA.

1.	Alameda Sugar Company	Alvarado
2.	American Beet Sugar Company	Oxnard
3.	California and Hawaiian Sugar Refining Company	Crockett
4.	Chino Valley Beet Sugar Company	Chino
5.	Los Alamitos Sugar Company	Los Alamitos
6.	Spreckels Sugar Company	Spreckels
7.	Union Sugar Company	Santa Maria
8.	Western Beet Sugar Company	Watsonville

CALF FEEDING.

The proper growth and development of the calf is equally as important as the care of the full-grown cow, for good cows cannot be made out of poorly fed calves. Whether the calf be destined for the dairy or for the shambles, the true principle is to keep it in a thrifty growing condition until the end is reached. It is not necessary that the calf be fat—in fact, it is better not to be so. The feed should be such as to produce bone and muscle to form a strong framework with which to produce milk or upon which to lay fat in the time of maturity. The mother's milk, if it be not too rich in fat, furnishes the best food for the purpose, but in our commercial dairying butter fat can be disposed of at a higher price if made into cheese or butter and a substitute offered which is cheaper.

If the calf is to be raised on skim milk as the principal food, it should receive fresh whole milk for the first ten days or two weeks. Then substitute skim for whole milk, a little at first and increase gradually until, by the time the calf is three weeks old, it may receive no whole milk whatever. As soon as this substitution begins add a small handful of wheat middlings to the ration and increase the quantity gradually as the skim milk is increased. Induce the calf to eat dry grain and hay as soon as possible, and give the milk simply as a drink. It will be remembered that skim milk is highly nitrogenous, and to make it a perfect food requires the addition of carbonaceous material. Nothing supplies this any better than corn meal, but, owing to its high price, rolled barley may be used, mixing barley, wheat, bran, and middlings in equal parts and feeding from one to two quarts per day by the time the calf is two months old.

In the case of feeding whey one may begin when the calf is about two weeks old by adding a little to the regular ration of whole milk and increasing the portion, as suggested above with skim milk, until the calf is a month old, when the milk may be taken away entirely. Unlike skim milk, whey is more largely carbonaceous, owing to the removal of the casein as well as the butter fat. Thus the grain ration should contain more protein than for skim-milk feeding, and for this reason some linseed oil-cake meal should be added to the middlings as soon as the whey is fed. Whenever the calf can be induced to eat the grain dry, give a mixture of two parts each of bran and middlings and one part of linseed meal. The calf developes a stronger digestion if it can be early induced to eat hay and its grain dry, and drink the milk or whey alone. The chief difficulties in feeding whey arise from permitting it to sour before feeding and depending upon it as the sole food. While it may be possible to raise fairly good calves on skim milk alone, it should never be attempted with whey, because the latter contains only about two-thirds as much food substance as the former. Both should always be fed sweet. The amount of grain necessary depends upon the quality of hay or pasture to which the calf has access. The hay should preferably be alfalfa.

HORSE FEEDING.

In making up rations for horses we must remember that the digestive organs of this animal differ materially from those of the cow, the former having but one stomach while the latter has four, three of which are used, in the main, to prepare the food for the fourth or true stomach, which corresponds to that of the horse. For this reason horses cannot assimilate as much from a bulky or coarse ration as is noted for the ruminants. Consequently when a horse is being heavily worked intelligent care must be given to the feeding. For instance, from thirty-five to forty-five pounds of silage can be fed daily to the cow, but less than one-third of that amount should constitute the daily portion for the horse.

When feeding cows it is generally considered best to have the grain or concentrated part of the ration form about one-third of the total dry matter, whereas, in the case of feeding horses, heavily worked, the proportion of grain may exceed one-half the total amount of food. One reason for using so much grain is in order to be sure that we have in the ration a generous amount of protein, so essential to the successful feeding of the horse.

In alfalfa sections so much protein can be supplied in green and cured alfalfa that much less grain is required than is necessary when the roughage consists of cereal hays only.

The following balanced rations for animals weighing 1,000 pounds illustrate this point:

	1.		2.		3.		4.
Lbs.	Material.	Lbs.	Material.	Lbs.	Material.	Lbs.	Material.
12	Alfalfa hay	15	Alfalfa hay	9	Alfalfa hay	10	Alfalfa hay
11	Wheat "	9	Wheat "	12.5	Barley "	12	Barley "
7	Crushed Barley	6	Cracked corn	7	Crushed Barley	7	Cracked corn
Nutritive ratio,	1:5.7		1:5.6		1:5.6		1:5.9

For a horse at light work 12.5 pounds of alfalfa hay with the same amount of cut straw forms a balanced ration. It may be mentioned that it is more economical, and also better for the digestion, to cut all the roughage.

If barley hay, rolled barley and cottonseed meal were the feeds in question, the ration would consist of 15 pounds barley hay, 12 pounds crushed barley, and 1 pound cottonseed oil-cake meal. This ration would be much more expensive than either of the others quoted above.

Colt Feeding.—No general rules can be laid down for the feeding of colts; but, as in the case of the calf, it is very necessary that proper care should be exercised in the selection of foods. Cow's milk may be substituted, if necessary, for that of the mare. The colt should be taught to eat grains, any of which may be fed to advantage: the choice would depend on ruling prices. At times, when the colts are teething, it will be found more profitable to warm and moisten the grain ration. Hay of first quality, preferably alfalfa, should be fed in conjunction with the grain, so as to properly develop the digestive system.

SWINE FEEDING.

The same principles hold true in pig feeding as with other animals. Inasmuch as the largest demand is now for small pork, the aim of the feeder should be to produce as much growth as possible in a short time. The rations, therefore, should be rather nitrogenous, having a high percentage of protein when the pigs are young, or as soon as they begin to eat, and increasing the carbonaceous portion as they grow older. This principle is illustrated in the Table IV of feeding standards. We give two rations, one for alfalfa regions and the other for sections where alfalfa is not grown. Both rations are calculated for fifty pigs weighing about fifty pounds each, and can be changed in proportion as the pigs are lighter or heavier. The age of the pigs is supposed to be from two to three months:

Rations for 50 Pigs Averaging 50 Pounds Each.

Lbs.		Dry Matter.	Protein.	Carbohydrates.	Fat.	Nutritive Ratio.
30	Middlings	26.5	3.70	16.00	1.10	
50	Ground barley	45.0	4.80	31.70	1.00	
20	Alfalfa hay	17.8	2.46	7.42	.32	
200	Skim milk	18.1	6.60	10.60	.20	
	Total	107.4	17.56	65.72	2.62	1:4.1
10	Linseed meal	8.9	2.60	3.80	.70	
35	Corn meal	30.8	2.24	23.17	1.19	
55	Middlings	48.5	6.71	29.37	2.09	
200	Skim milk	18.1	6.60	10.60	.20	
	Total	106.3	18.15	66.94	4.18	1:4.2

The alfalfa hay may be fed in the long state, but the most economical way is to cut it in a cutting machine and mix with the grain and skim milk, allowing the mixture to soak twelve hours before feeding. If feeding green alfalfa, calculate 4.5 pounds of green for one pound of hay.

Alfalfa is one of the cheapest foods known for growing pigs, and so far as experiments show it furnishes the only pasturage upon which pigs may be kept without any other food. If expected to make much growth the pasture should be supplemented with some extra food.

POULTRY FEEDING.

The proper feeding of laying hens and other poultry should be conducted on the same lines as that of other farm animals. There are similar losses and wastes as are found in mammals, and there is the same necessity for replacing and replenishing the tissues, fluids, etc. of the body.

We must of necessity know the composition of the body of the fowl and of the egg, but after that we do not have to make new laws nor found new principles, but have merely to adapt the knowledge we have gained from the investigations made for other animals, to the hen; modifying rules and rations to suit the case in question. The scientific research called for, and urgently too, is that of ascertaining the digestibility of the different foods fed to the hen. For the cow, sheep, horse, and swine we have the digestive coefficient for almost every food consumed, while for the hen we have very few reliable data with which to work; and in view of the great value of the poultry industry it should receive more scientific attention than is at present allotted to it.

Many of the foods used for poultry are identical with those consumed by the cow, and the analysis of the remainder of the foodstuffs necessary for poultry, shows them to have the same ingredients as the others. Hence the principles expounded for the rational feeding of cows and other animals apply equally well to the nutrition of fowls. When feeding growing chickens the main object is to supply sufficient nourishment to insure hardy growth. In the case of the mature hen, it is a somewhat more complicated proposition. The feeder must bear in mind the fact that the eggs are also the product of the transformation or assimilation of the food eaten, and the nature of the ingredients of the nourishment requisite for their production is best seen by an examination of the composition of eggs, shown in Table VII.

TABLE VII.—Analyses of California Eggs.

1.—Proximate Analysis.

Shell, 10.81%; yolk, 32.47%; white, 56.42%.

2.—Composition.

	Shell.		Yolk.		White.	
	Parts per 100.	Referred to Entire Egg.	Parts per 100.	Referred to Entire Egg.	Parts per 100.	Referred to Entire Egg.
Water	....	....	49.70	16.13	36.48	48.79
Protein	....	....	15.54	5.05	12.07	6.81
Fat	....	....	33.43	10.85	.23	.13
Carbonate of Lime	93.75	10.14				
Carbonate of Magnesia	.95	.10				
Phosphates	.95	.10	1.04	.34	.55	.31
Alkalies, etc.	....	....				
Organic matter and water	4.35	.47				
Undetermined	....	....	.29	.10	.65	.38
Total	100.00	10.81	100.00	32.47	100.00	56.42

The yolk and white contain water, protein, fat, and a small percentage of mineral matter, while the shell consists almost entirely of mineral matter of which carbonate of lime constitutes 94% or over 10% of the entire weight of the egg. That is, in one dozen good sized eggs there are fully 2.5 ounces of carbonate of lime, familiar to all under the name of marble. We thus have proved to us the absolute necessity of a generous supply of lime in the diet of the hen.

In feeding other farm animals the quantities consumed per day are termed rations and the standards calculated for 1,000 pounds live weight; consequently, in order that the rations for fowls may be comparable with these standards, we will give the requirements for 1,000 pounds live weight, which for hens averaging three pounds is:

Dry matter.	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.
52	8.4	4	33	1:5.0

Calculating this for 100 hens, we have respectively:

16	2.52	1.2	9.9	1:5.0

The analyses of the foods available for poultry feeding and compounding rations will be found in Tables I, II, and V.

From the data given there, the rations given below have been calculated.

Ration 1

6 lbs wheat
2 lbs bran
2 lbs middlings
5 lbs crushed barley
1 lb cocoanut oilcake meal
4 lbs alfalfa hay
.75 lb blood meal

Ration 2

11 lbs wheat
3 lbs bran
4 lbs middlings
2 lbs alfalfa hay
1 lb meat meal

Ration 3

1 lb wheat
3 lbs bran
5 lbs crushed barley
5.6 lbs cocoanut, oil-cake meal
5.5 lbs alfalfa hay

Ration 4

7.0 lbs wheat
3.5 lbs bran
2.0 lbs alfalfa
4.5 lbs crushed barley
1.0 lbs meat meal

Ration 5

9 lbs ~~bran~~ oats
5 lbs middlings
5 lbs bran
15 lbs skim milk

Mineral Matter.—While the above-mentioned rations are balanced with reference to the organic ingredients, they are not so when the mineral or inorganic constituents are considered; particularly is this true in the case of lime. If all the mineral matter in the foregoing rations were lime it would not be sufficient to meet the requirements for the eggs which the hens consuming the food would lay. We therefore see that lime must be supplied otherwise than by food.

Wastes of the Hen.—The mineral matter of the food eaten is not entirely assimilated by the body. And the composition of the hen manure, given below, proves that this is likewise true of the nutrients.

COMPOSITION OF HEN MANURE.

Water	56.00
Organic matter	25.50
Nitrogen	1.60
Phosphoric acid	1.75
Potash	.85
Lime	2.25
Magnesia	.75
Insoluble residue, etc.	11.30
Total	100.00

The unassimilated fat and carbohydrates are included in the "organic matter", and the undigested portion the "nitrogen."

The Lime Supply.—One of the best materials that a poultryman can use for supplying the requisite lime is oyster shell, or any other variety of shells. An experiment in this direction was made at the New York Experiment Station, and the result was such that the use of oyster shells during the laying season, where they can be cheaply obtained, was strongly recommended. It was found there that one pound of oyster shells contained sufficient lime for the shells of about seven dozen eggs.

Shells are not the only source for the lime necessary for egg shells. Bones also contain a large percentage of lime as is seen from the following analysis of clean dry bones of oxen and sheep:

	Per cent.
Carbonate of lime	6 to 7
Phosphate of lime	58 to 63
Phosphate of magnesia	1 to 2
Fluoride of calcium	2
Organic matter	25 to 30

Fresh green bones also contain, besides the lime compounds, some protein or flesh-formers, which add to its value as a poultry food. The best way to render the bones available is to have them broken by means of the bone cutter. One pound of the green bones is generally considered sufficient for sixteen hens. Besides the cut bones or oyster shells, the hens must have a generous supply of some kind of grit, very coarse sand or broken crockery. This grit serves as teeth for the hens, and when they are unable to obtain it indigestion and other ailments are sure to follow.

Necessity of Variety of Foods.—An examination of the rations given on page 46 proves that in order to have the proper proportions of the different ingredients, or to balance the ration, we must have a variety of foods at our command. It would be impossible to make a balanced ration solely from the grain feed-stuffs. If the necessary amount of flesh-formers is obtained by the use of grain, then the fat and heat producers in the ration will be greatly in excess; on the other hand, if the carbohydrates or fattening ingredients are made the standard, then when the proper proportion of this part of the food is supplied by the grain, the flesh-formers will be lacking to a considerable extent.

We have to depend on the peas, beans, different oilcake meals, blood meal or dried blood and fresh meat or meat meal for supplementing the deficiency of the flesh-formers.

By fresh meat is meant *lean* meat with the minimum amount of fat. Buyers should be careful in regard to this point, as a large per-cent of fat would be worse than useless for the purpose of the feeder.

All of these as noted in the tables are highly concentrated foods, the richest and most costly being dried blood or blood meal, containing about 80% protein, which is nearly twice the corresponding figure for meat meal and approaches four times the rating of this ingredient in the pea and bean. It probably varies less in composition than any of the foods in question. Experience has proved that the best results are obtained when some animal food forms a part of the ration in about the proportions shown in the foregoing rations.

The nutritive ratio of the ration, or the ratio between the flesh-formers and fat and heat producers, should vary according to the maturity of the hen and the period of feeding. The nutritive ratio in the case of growing chicks should be narrower than when the hen is mature or when she is being fattened for the market.

When the hens are not laying they only require a maintenance diet which is not as rich a one as that for hens during the laying period, either in flesh-formers or fat-formers and heat-producers; neither is there any necessity for the oyster shells or substitutes.

Foods for Growing Fowls.—The amount of food required for growing chicks and pullets is larger than that for full-grown fowls. According to Professor Wheeler of New York State Station the quantities of water-free food requisite for every one hundred pounds live weight fed, is 10.6 pounds at about one pound average weight; at two pounds live weight, 7.5 pounds; at three, 6.4 pounds; at four, 5.5 pounds; at five, 5.3 pounds; at six, 4.9 pounds; at seven, 4.7 pounds; at eight, 4.0 pounds; at nine, 3.3 pounds; at ten, average weight, 3.2 pounds of food. The amount of green or fresh food equivalent to the above different weights would be correspondingly increased. Professor Wheeler further states that these are the amounts taken by the growing fowls which normally attain to the higher weights given, and which are still immature and growing rapidly when at five and six pounds average weight.

Water.—The great necessity of water for the hen is shown by the high content of this element in the body and also in the egg. In one dozen eggs there is almost one pint of water. About four gallons of palatable water (one that is suitable for domestic purposes) are required per day for one hundred hens. Too much stress cannot be placed on the necessity of having good water, as impure water will undoubtedly cause sickness among the poultry. The more "green" food consumed the less will be the quantity of water needed.

FOOD VALUE OF FRUITS FOR LIVE STOCK.

The use of fruits as a part of the food for stock is exciting more attention on the part of the horticulturist every year. In almost every orchard there is some fruit which cannot be placed on the market. The chief causes for this are (1) the "windfalls," which are generally immature, and even if first-class, the fruit would be bruised or injured to such a degree as to preclude its sale. (2) Freights may be so high, and prices so low, as to leave no profit to the grower in any but the best of the crop; and sometimes even for that he receives very small returns.

The question, then, is what to do with the fruit? The idea naturally suggests itself to the orchardist to feed the fruit to cattle and hogs. But he is undecided as to its merits as a food for the animals and, as to the comparative value of the different fruits on the one hand and the grains and various feeding-stuffs on the other. The object of this article is to throw some light on the subject, and the following table, containing the analyses of some of the different California fruits, has been prepared in a similar manner to those of cattle-foods given above. Comparison between the grain and fruit may be made by referring to Tables I and II.

TABLE VIII.—Composition of Fruits.

A.—Edible Portion. Percentage Composition.

	Water.	Ash.	Protein	Fiber.	Sugar, Starch, etc.	Fat.
Apples	84.80	.50	.40	1.50	12.5	.30
Oranges	88.30	.41	.76		10.53	
Apple pomace	76.70	.50	1.40	3.90	16.20	1.30
Pears	83.90	.54	.56	2.73	11.46	.79
Plums	78.40	.52	1.00		20.18*a*	
Prunes (all)	80.20	.47	.85		18.48*a*	
Apricots	85.07	.48	1.04		13.41*a*	
Nectarines	82.90	.49	.63		15.99*a*	
Figs	79.11	.58	1.50		18.79*a*	
Grapes	80.12	.50	1.26		....	
Watermelons	90.25	.81	1.07		7.86*a*	
Watermelons (rind)	89.97	1.24	1.43	1.41	5.59	.36
Watermelons (pulp and juice)	92.07	.30	.76	.47	5.80	.60
Nutmeg melon (entire)	90.18	.66	.60	.48	7.85	.23
Raisins	18.95	2.24	4.50		67.71*a*	
Dried prunes	25.00	1.79	3.21		70.00*a*	
Dried apricots	25.00	2.42	5.23		67.35*a*	
Dried peaches	25.00	2.14	2.76		70.03*a*	
Dried figs	25.00	2.08	5.40		67.52*a*	

a Chiefly sugar.

TABLE VIII.—COMPOSITION OF FRUITS. (*Continued.*)
B.—Amount Digestible in 100 Pounds.

	Protein.	Carbohydrates.	Fat.	Nutritive Ratio.
Apples	.30	12.80	.2	1:44.2
Oranges	.57	9.66	....	10.9
Apple pomace	1.00	11.90	1.10	24.7
Pears	.42	12.90	.63	33.7
Plums	.75	18.40	....	24.4
Prunes (all)	.64	17.89	....	27.9
Apricots	.78	13.04	......	16.7
Nectarines	.49	15.77	....	32.2
Figs	1.12	17.95	....	16.0
Grapes	.95	17.72	....	18.6
Watermelons	.81	5.90	....	7.3
Watermelons (rind)	1.08	4.20	.28	4.5
Watermelons (rind, pulp, juice)	.57	4.58	.48	9.7
Nutmeg melon (entire)	.45	5.89	.18	14.0
Raisins	3.38	65.18		19.3
Dried prunes	2.42	67.80		16.7
Dried apricots	3.92	65.46		27.9
Dried peaches	2.14	68.07		32.2
Dried figs	4.03	64.62		16.0

NOTE.—In fresh stone fruit six per cent of the entire weight consists of pit. In dried fruit the corresponding percentage is about doubled.

Comparisons from the Tables.—Viewing these tables side by side, we note that the fresh fruits contain from eight to ten times as much water as do the grains and meals. Hence, equal weights of the two classes of foods could not be used with the expectation of obtaining from each the same nutritive value. This is true, even if the proportion of the nutrients were alike in fruits and grains; but the ratio is far from being similar, as is shown by glancing at the nutritive ratio of the different materials. Among the grains and meals the ratio is much narrower, and more nitrogenous, than in the case of fruits; that is, in the fruits there are more carbohydrates, for the same amount of protein, than is noted for the grains.

The next question is, how to compare the two kinds of foods? Suppose we try on the basis of the protein or nitrogenous part of the material; and for this comparison we will take wheat on the one hand and fresh apricots on the other. The former is a good average of the grains, and the latter of the fruits. The following little table shows the respective contents of the nutrients in 10 pounds wheat, and a like quantity of apricots, edible portion, which will be about 10.6 pounds whole fruit:

	Water.	Ash.	DIGESTIBLE.			Fuel Value (Calories.)	Nutritive Ratio.
			Protein.	Carbohydrates.	Fat.		
10 lbs Wheat	1.14	.17	.91	6.42	.10	14,060	1: 7.3
10 lbs Apricots (fresh)	8.51	.05	.08	1.31	....	2,570	1:16.7

We perceive that wheat contains over eleven times as much nitrogenous, or flesh-forming, ingredients as we find in fresh apricots; in other words, it would require 11 pounds of apricots to equal 1 pound of wheat. The same can be said of nearly all the other fresh fruits. Even in the case of figs, which yield, among the fresh fruits represented, the highest protein per cent., we would require 8 pounds to equal 1 pound of wheat in respect to this highly important element of the food. Hence we might say, in general, that the grains are from eight to twelve times as rich in muscle-forming material as are the fruits.

When we compare the foods as regards the carbohydrates (sugar, etc.), or heat-producers, the comparison is not so disadvantageous to the fruits. The wheat has only about five times the content of carbohydrates that is given for the apricots, as is shown by the figures 6.42 for wheat, and 1.31 for apricots; 5.3 pounds of apricots will have as much fattening ingredients as will 1 pound of wheat.

For some of the other fresh fruits, as figs, grapes, prunes, and plums, the proportion is still more favorable—from 3 to 4 pounds only of the fruit are equivalent in carbohydrates to 1 pound of grain, whereas in the melons the corresponding figures are from 10 to 12. Dried fruits make, naturally, a far better showing, as they more nearly approach in food value the grains, meals, etc. The following tabular statement illustrates this fact:

10 lbs. wheat contain .91 lbs. protein and 6.42 lbs. carbohydrates
10 lbs. raisins contain .34 lbs. protein and 6.52 lbs. carbohydrates

It is thus seen that the carbohydrates in the two materials are almost identical, and that the protein in the wheat is less than three times the amount found in raisins, which are a fair example of dried fruits. An inspection of the figures given for the fuel value, expressed in calories, will show the capacity of the different materials for producing heat and energy; the grains and meals rating from about four to twelve times higher than the fresh fruits, while the dried fruits do not differ materially in this relation from wheat and its by-products, and cocoanut-cake meal.

The fuel-value data alone, however, are not sufficient to determine the nature of the food; that is, whether nitrogenous or starchy. We must know the protein, or flesh-forming ingredients, in addition to the fuel value, in which case we can tell the kind of material in question.

How to Use Fruit in Feeding.—It would seem, from the foregoing, that the feeder is in a dilemma. If he wishes to give the necessary amount of protein to the animal by means of most of the fresh fruits in place of grain, he will have to add two or three times the requisite quantity of fattening or heat-producing ingredients—an addition not generally sought after. On the other hand, if the carbohydrates are made the standard, then when the proper amount of this part of the food is supplied by the fruit, the protein will be lacking to a considerable extent. It appears then, that, the best way out of the difficulty would be to use enough fruit to supply the fattening elements of the food, and make up the deficiency of flesh-forming material from some concentrated nitrogenous food, as cotton-seed meal or cocoanut meal. In this way the ration will be complete and more economical than if no fruit were used.

To illustrate: A cow (1,000 pounds weight) requires per day about 25 pounds of dry matter; containing 2.5 pounds of digestible protein, 12.5 pounds of carbohydrates, and .40 pounds of fat, with a fuel value of 30,000. If we have hays, grain, and bran, a good ration would be 12 pounds of alfalfa hay, 13 pounds of wheat hay, and 5 pounds of bran. The 5 pounds of bran could be replaced by 15 pounds of fresh prunes, and the deficiency in the protein resulting from the substitution could be made up with 1 pound of cotton-seed meal; or 5 pounds of raisins could take the place of the prunes, in which case ¾ pound of cotton-seed meal would suffice for the needed amount of protein. Either of the above changes from the conventional ration would make it complete with respect to its contents of digestible nutrients. But the objection might be raised, and with just cause, that the ration would prove very laxative. To obviate this, it would probably be best to use a less amount of fruit and mix it with bran or middlings, etc., to prevent "scouring" the animal. A little careful experimenting on the part of the feeder would soon settle the matter.

Equivalent Values of the Fruits, Grains, etc.—It would be almost impossible to compare the fruits and grains by means of their nutrients, because the ratios of the muscle-forming material to the fattening matter in the two kinds of foods are so different. But what can be done is to compute the valuation of each on the basis of 1.7 cents per pound for protein, 3.31 cents per pounds for fat, and 0.75 cents per pound for carbohydrate. These values are an average for those given in the Eastern and Middle States, and are, therefore, for this State only approximate, but sufficiently accurate for our purpose. Table IX is calculated from Tables V and VI, with the aid of these rates. A glance at this table gives us, perhaps, a better idea of the relative values of the foods under discussion, than could be obtained in any other way.

TABLE IX.—Showing Comparative Value of Fruits, and Hay, Grains, etc.

	100 Pounds Fruit Equivalent to Pounds of											
	Wheat straw.	Alfalfa hay.	Oat hay.	Corn.	Barley.	Oats.	Wheat.	Wheat bran.	Wheat middlings.	Rice bran.	Cotton-seed meal.	Cocoanut cakemeal.
Fresh Fruits.												
Apples	34	20	24	15	15	17	16	18	16	13	9	13
Oranges	33	19	23	14	14	16	15	17	15	12	8	12
Pears	40	23	30	17	18	20	19	20	19	15	11	15
Plums	50	30	36	22	24	25	24	26	24	20	14	20
Prunes	46	27	33	20	22	23	22	24	22	18	13	18
Apricots	40	23	29	17	18	20	19	20	19	15	11	15
Nectarines	43	26	30	19	20	22	21	23	21	17	12	17
Figs	50	30	37	23	24	26	25	27	25	20	14	20
Grapes	50	30	37	23	24	26	25	27	25	20	14	20
Watermelons	22	13	16	10	10	11	11	12	11	8	6	8
Nutmeg melons	19	11	13	8	9	9	9	10	9	7	5	7
Dried Fruits.												
Dried prunes	175	104	125	78	82	88	84	92	84	67	48	68
Dried apricots	194	115	138	86	90	97	93	102	93	74	53	76
Dried peaches	190	113	135	85	88	95	91	100	91	72	51	74
Dried figs	186	110	132	83	85	93	89	97	89	71	50	72
Raisins	216	128	153	97	100	108	103	111	103	82	59	84

It is seen that the least valuable of the fresh fruits mentioned in the tables are the melons, 100 pounds being equal to only 6 pounds of cottonseed meal, about 10 pounds of the grains, 5 pounds of hay, and 20 pounds of straw.

Apples and oranges are practically equal in food value, rating about fifty per cent. higher than the melons, as is seen by the figures for the equivalents of 100 pounds of these fruits, *viz.*, 24 pounds of hay, 16 pounds of grains, 13 pounds of rice bran and cocoanut meal, and 9 pounds of cotton-seed meal.

A good average of the pitted fresh fruits is represented by prunes, 100 pounds of which are equal in nutriment to 46 pounds of wheat straw, 27 pounds of alfalfa hay, 33 pounds of oat hay, 20 pounds of corn, 22 pounds of barley, 23 pounds of oats and wheat and its products, 18 pounds of rice bran and cocoanut meal, and 13 pounds of cotton-seed meal.

Hence, if wheat bran costs $15 per ton, fresh prunes would be worth as a substitute $3 per ton; likewise, if cottonseed meal is selling for $30 per ton, the prune value would be about $3.75. At the market price of oat hay, the figure for fresh prunes should be nearly $3 per ton.

The amount of nutrition found in grapes and fresh figs is identical, both rating about equal, as fodders, with the pitted fruits.

The dried fruits, as before stated, rank far above the fresh material as stock feed. This is amply proven by the table. Of the dried fruits represented in the table, raisins lead in food value; containing 1¼ to 1½ times the nutritive ingredients of alfalfa and oat hays, respectively; 100 pounds of the fruit being practically equal to the same quantity of grain, but to only 82 pounds and 59 pounds, respectively, of rice, bran, and cotton-seed meal.

Dried apricots rank slightly lower than raisins, owing to the latter containing less water. Apricots, however, are of equal value as a feeding-stuff with wheat bran; that is, the unsalable, dried apricots are worth to the orchardist about $15 per ton for feeding purposes.

It may be a difficult question at times to decide, when prices are extremely low, which would be the better economy: To feed the fruit to cattle, or to receive whatever small returns might be offered for it in the market. In such emergencies, a short soliloquy and a little arithmetic will decide the whole matter.

When there is no market for the fruit there is sometimes nothing left to be done but to feed it to stock. Under any circumstances, when stone fruit is used for fodder for hogs, it is be feared that when the animals crack large quantities of pits, poisoning may occur from the oil of bitter almonds and prussic acid present in the kernels. Precaution in this direction is unnecessary for stock, as they do not crack the pits. The stones or pits can be used to great advantage as fuel in the economical management of the farm.

Feeding Test.—A practical application of the foregoing was made by a feeder in the northern part of the State. He experimented, with a large sow, from which a litter of pigs had just been taken, by first feeding her a lot of dried figs and barley for about a week, to get her accustomed to the fig diet. She then weighed 260 pounds. For 9 days following she was fed all the dried fruit she would eat, consuming

220 pounds, or 24.4 pounds per day. Her weight had increased to 290 pounds, showing a gain of 30 pounds in nine days, or 3⅓ pounds per day.

It must be remembered that this sow was in an unusually favorable condition for a rapid increase in weight, having just been depleted by the litter of pigs; hence the above comparison is not fully demonstrative; and unfortunately we have no data for gain on full grain ration from the same place. But from investigations made at the Utah Agricultural College (Bulletin 40) the increase in weight per day of hogs weighing from 250 to 300 pounds, on a full grain ration, was about 1½ pounds. Hence we might conclude that pigs will increase in weight more rapidly from a ration of dried figs than from one of grains, etc. The gain in live weight per day from the amount of dried figs consumed (24.4 pounds) was 3⅓ pounds—that is, 1 pound gain required 7.3 pounds figs. This result agrees very closely with the figure 7.13, obtained at the Utah Station, for the number of pounds of grain necessary to produce 1 pound of gain in pigs of the same weight as the one in question.

It must be noted that, although 1 pound gain requires the same quantity, practically, of either the grain or figs, the pigs will consume about three times as much of the figs as they will of grain; therefore the gain will be correspondingly more rapid. Assuming the basis above discussed to be correct, this is a very important point if one wishes to place his hogs, of a given weight, in the market as soon as possible.

The thirty pounds gain was due to the 220 pounds of dried figs consumed. Hence at the selling price of the sow, 4½ cents per pound live weight, the amount realized for the figs was $1.35, which is equal to about $12.50 per ton, a somewhat low figure for the fruit. But the use of it as pig-feed saved the purchase of grain, and at the same time added 30 pounds to the weight of the animal in less than one-half the time that would have been necessary had grain been fed. The cost of the cereal ration, based on the ruling price of grain at the time of the experiment to produce the same gain, would have been about $2.00, which, at the selling price mentioned above, would have entailed a loss.

From the foregoing data it is seen that 200 pounds of a grain ration would be required to produce the same gain in weight as resulted from the experiment with figs. This corresponds quite well with Table IX.

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UNIVERSITY OF CALIFORNIA—COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

E. W. HILGARD, Director.

TOLERANCE OF ALKALI BY VARIOUS CULTURES

BY R. H. LOUGHRIDGE.

BRANCH OF "ALKALIED" PEAR TREE.

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EXPERIMENT STATION STAFF.

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E. J. WICKSON, M.A., *Horticulturist and Superintendent of Agricultural Grounds.*
R. H. LOUGHRIDGE, Ph.D., *Agricultural Geologist and Chemist.*
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RESULTS OF OBSERVATIONS—CONTINUED.

TOLERANCE OF ALKALI BY VARIOUS CULTURES.

BY R. H. LOUGHRIDGE.

Alkali studies at this Station have thus far been chiefly directed toward the occurrence, character, and reclamation of alkali lands in California, the chief salt of which was carbonate of soda, the basis of black alkali; and several bulletins and reports on the subject have been printed and distributed very generally by the Station. Among these Bulletin No. 128, issued within the past year, is very full and comprehensive and can be had by application to the Station.

A few observations have been made with reference to the power of certain cereal and fodder crops to withstand the effects of alkali, and the results are given in the Annual Report of 1896. But as a rule the amounts were ascertained for a depth of one foot only, because at the Chino substation the greater part of the salts was held within that depth, and the majority of the cultures observed had shallow root-systems. The results have not, therefore, that value which would have been reached by deeper examination of the soils.

In the past two years, however, we have extended the investigations and have endeavored to ascertain, as far as possible, the highest amount of each salt occurring in four feet depth in which the different cultures of all kinds—orchard, as well as others—will grow and come to maturity; for while it is true that it is the alkali within the first foot or two of the surface that is liable to produce the chief injury upon the roots of the plants, it is certain that there will come a time in the cultivation of the land when nearly all of the salts that lie in the lower depths of the soil will be reached and dissolved by the water that has been given to the soil either by rainfall or by irrigation in sufficient amounts to percolate downward to it, and will be brought up and concentrated at or near the surface. This has occurred in the substations at Tulare and Chino.

It is this concentration that has proved so destructive to many cultures that for a time have done well; and it is this total amount within reach of water that must be considered when orchard trees or perennial crops are planted, if the farmer wishes to avoid the agony of seeing his work and hopes of years swept away by the sudden activity of an enemy which has been hidden in the lower depths of his land.

All of this injury to cultures was at first naturally attributed either to the content of carbonate of soda in the surface foot, where its corrosive action on the tender bark of the root crown could be felt, or to the very large amount of total salts which might produce stagnation of the sap or other injury to the feeding rootlets. Some analyses and observations were made at that time both on the amounts of alkali which caused suffering, and on the amounts in soils where no trouble appeared; the results are given in previous reports.

The depth of four feet has been adopted as the proper one, because investigations in the San Joaquin Valley and in the valley of Southern California have shown that in all but the sandiest of soils the substrata below that depth, while not entirely free from alkali salts, contain so little and are so commonly beyond the depth to which rainfall or irrigation water penetrates or the effect of subsequent surface evaporation is felt, that the consideration of their content of alkali is unimportant.

Utilization of Alkali Lands.—The proper utilization of alkali lands implies a due regard on the part of the farmer to the several conditions accompanying the alkali deposit, each of which has its influence upon the method of treatment to be pursued in the reclamation of the land, in the selection of suitable crops, and in their cultivation and irrigation. These conditions are, *first*, the *nature* of the alkali salts, whether chiefly carbonate (black alkali), sulfates, or chlorids (common salt); *second*, the *position* of the alkali in the soil-column, whether near the surface or several feet below; and, *third*, the *amount* of these salts contained within reach of the plant, or which would at some time rise to the surface. These several conditions have repeatedly been treated of in the several Station publications on the subject of alkali, but it seems to be important that they be briefly given again here.

The examination of the soil to a depth of five or six feet in localities where alkali either is known or is suspected to exist is of course the first thing of importance, and an average sample of each foot in depth should be taken; the result of the chemical examination of these will clearly indicate the conditions to be met.

First, with regard to the nature of the salts: Carbonate of soda (black alkali), if present, may be neutralized by the application of gypsum in an amount exceeding that of the carbonate present; rainfall or irrigation water will dissolve this, and as rapidly as the solution comes in contact with the carbonate the latter will be converted into the far less harmful sulfate or glauber salt. This will, of course, increase the amount of the sulfate, and if then this salt is too great for the tolerance of plants it must be removed by drainage, or driven deeply into the lower depths of the soil by copious irrigation. Common salt and the sulfates ("white alkali") can be successfully treated only by removal from the soil limits of five or six feet depth. Nothing can be applied that will render them harmless when they are present in amounts exceeding the tolerance of crops. This removal from the soil may be done either by underdrains of tiles at a depth of four feet, the alkali drainage-water being conducted into a stream, or into a well dug for the purpose to underlying gravel, or, as has been done at the Tulare substation, into a natural sump; or by deep ditches into which the alkali-charged water may enter by seepage from flooded areas. Alkali is quickly soluble in water and rapidly percolates downward into the soil if the latter is at all leachy, and it would be practically impossible to wash it off of the soil by flooding and shallow surface drains. A surface inch of water soaks to about six or eight inches depth in a sandy soil, and to four inches in one more clayey.

Second, the position in the soil-column: Where the alkali is at the surface suitable means toward reclamation or removal must be adopted as indicated above, or the alkali must be made to sink to a depth of several feet and kept there out of the reach of the tender plant-roots; or crops must be chosen suitable for the character and strength of the alkali.

On the other hand, where the alkali is *not* at the surface, either such shallow-rooted crops should be planted whose roots will remain above the alkali zone, and such cultivation and irrigation be given that the mass of alkali at several feet depth is not disturbed, or the alkali must be driven deeper into the soil and kept there; or such crops should be selected as may be able to tolerate the amount of alkali occurring in the entire soil, whether that alkali be subsequently concentrated near the surface or distributed throughout the three or four feet. The roots of deep-rooted crops and trees may be able to remain in the upper soil for awhile, but they soon grow downward to the vicinity of the alkali and are affected.

Third, a careful selection of such cultures should be made as are known to withstand the amount and nature of alkali present. For instance, the apple is apparently severely injured by the presence of 3,000 pounds of common salt per acre in four feet; while the olive grows well at Tulare in a soil containing as much as 5,600 pounds of that salt per acre. While, therefore, olives would grow where apples died, it would be folly to attempt to raise apples on land with so large an amount of alkali simply because olives do well on it.

It is the hope of the Station to be able thus to ascertain the maximum or safe tolerance of the various cultures, either large or small, for either carbonate of soda, common salt, or the sulfate; so as to enable farmers to choose for such lands only those cultures that will probably succeed. It is thought that much alkali land might be put to profitable cultivation that now lies idle because, having proved incompatible to some one crop, it has been thought to be unsuitable for all.

Field of Observation.—The Tulare and Chino substations have thus far been almost the only fields of observation, while experiments on reclamation problems have been conducted at the former station at the same time.

The Tulare tract was originally chosen for the purpose of making its alkali land the subject of special study and investigation; and at that time but one large alkali spot was in sight on the surface, the rest being covered with native grasses and wildflowers. Alkali hardpan, however, did exist at depths of from twelve to thirty-six inches, and the necessary use of irrigation water has, by percolation to the alkali and subsequent capillary rise, brought the dissolved salts to the surface here and there over the tract, and produced a number of gradually enlarging alkali spots. This gave a larger field of reclamation work than had been intended at first, while at the same time enlarging the scope of observation on various cultures. The effect of this rise of alkali was seen in the

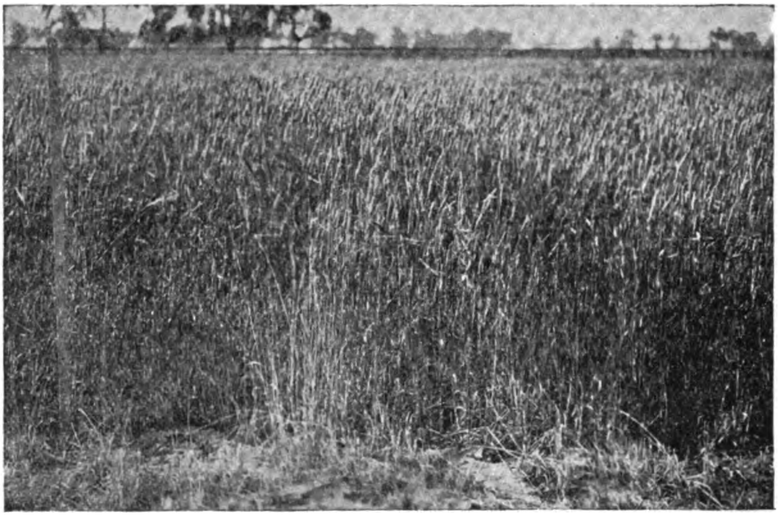


PLATE 1. Wheat Growing 3 Feet High in Soil Crusted with White Alkali, Originally a Barren Black-Alkali Spot. Tulare Experiment Substation.

blighted appearance of tree growths and other cultures that had at first been doing well, as well as in the bare spots so characteristic of "black alkali."

Reclamation of the black alkali has been carried on for a number of years, gypsum being applied, turned under and thoroughly watered. The result has been a very general conversion of the dreaded carbonate of soda into the far less harmful sulfate; and on spots where not a blade of grass would previously grow, there have been produced excellent wheat and barley, three or four feet high and full-headed, although the surface of the ground was at harvest time covered by a thick crust of white alkali. (See plate 1.) Photographic illustrations of this growth have been given in the Annual Report of the Station for 1897–8, and in Bulletin No. 128.

Experiments have also been made with respect to the removal of the alkali by underdrainage, through tiles, into a deep well; and also by carting away from spots where the alkali had, by deep percolation of irrigating water and subsequent rise by evaporation from the surface, been purposely made to come to the surface. Both methods were quite successful and large amounts of salts were thus removed from some of the alkali spots.

These are the only methods by which common salt and the sulfates can be removed from lands charged with them.

Injurious Nature of Common Salt.—The neutralization of the corrosive carbonate of soda in the alkali soils of Tulare by means of gypsum led to the belief that the various growths in orchard and vineyard and the smaller cultures would show very material improvement, but such anticipations have been but partially realized. It is true that the land was largely reclaimed from the evils of the carbonate of soda (black alkali), and that some of the cultures, such as wheat and barley, were enabled to grow and produce excellent crops, but other crops and trees still suffered from the effects of so-called *white alkali* (chlorid and sulfate of sodium, or common and glauber salt), from which the land had not been freed. Apple trees, for instance, were severely "alkalied," as partly shown in the photograph on page 13 (plate 2).

The injurious nature of *common salt* to plants in sea-coast lands has long been known, and has been largely attributed to the *bittern* (magnesium chlorid) that it contains; but the investigations at Tulare show that common salt in itself is highly injurious to plant growth. Its chief action seems to be that of an antiseptic which arrests development, or kills the nitrifying organisms in the soil.

It was therefore determined to make a detailed examination of the soils in which the various important cultures grew, and thus to ascertain the alkali conditions and the cause of suffering, and at the same time to make a study of the tolerance of the several salts on the part of the orchard trees. For this purpose the writer visited the Tulare substation in the summer of 1900, and, with the Inspector of Stations and the Foreman, selected trees and other cultures that were clearly suffering from alkali and those of the same variety that were doing well. Average samples of the soil of each foot to a depth of four feet were taken at a distance of about three feet from the tree, and from nearer other cultures. Photographs were also made. The results of the analyses of these soil-samples are of special interest in throwing new light on the tolerance of alkali by plants, and especially in that they bring forward prominently the evil effects of common salt, an enemy to crop production almost if not fully as dangerous as black alkali itself, though acting in a different manner. Heretofore its influence has been in a large measure overlooked, because of the reputation and prominence of carbonate of soda as an agent of destruction; and had not the land of the substation been so generally freed from the latter by the use of gypsum, the full power of mischief of common salt upon plant and tree growth would, perhaps, not have been brought out so well as in this investigation.

The fact that lands charged with carbonate of soda may be reclaimed from that particular salt by the use of gypsum makes the study of tolerance of the other ingredients of great importance; for if the soil, for instance, contained, in addition to the carbonate of soda, an amount of *common salt* that would in itself prove highly injurious to plant life, and which could not be leached out of the land by drainage, then the expense of the gypsum application to reclaim the black alkali would be useless; or if the conversion of the carbonate into the sulfate of soda by gypsum increases that already present to an extent approaching an amount not tolerated by plants, and no means of leaching and underdrainage exists, then the work of reclamation would also be useless. These points should all be considered by the farmer before gypsum is bought and reclamation of his land is begun.

Extent of the Investigation.—About one hundred varieties of cultures have been studied; these embrace orchard trees, grain and forage crops, grasses, vegetables, and other miscellaneous growths. The greater part of the results are valuable toward reaching the end in view, but others were disappointing in that the soils showed a far less amount of alkali salts than was indicated by surrounding conditions.

In many cases, several localities were chosen for the examination of the soil of the same culture, for it is impossible to judge of the nature and extent of alkali soils by the eye alone. For instance, many alfalfa fields in several parts of the State were sampled before conclusions at all satisfactory were reached, the majority having less than we had reason to believe.

The samples have all been carefully taken, each foot of the vertical soil-column being carefully mixed, in order that its sample may be an average of that foot. Many hundred analyses have been made with the assistance of Messrs. Colby, Snow, Lea, and Werthmueller.

A quick and at the same time accurate method of extracting the alkali from the soil has been adopted; instead of placing the dry soil on a filter and washing all of the alkali out with water, which often required two or more weeks in clay soils because of puddling by the carbonate of soda, a weighed amount is mixed with a measured quantity of water and allowed to digest for twenty-four hours with frequent shaking. The salts thus dissolved are thoroughly diffused through the liquid, and an aliquot part may be taken for evaporation and examination. If necessary, a portion may be passed through a filter to clear it from sediment, but very often the solution settles perfectly clear.

Difficulties in Interpretation of Results.—There are a number of conditions which may affect the interpretation of the results of alkali examinations and lead to erroneous conclusions with regard to the effect of alkali on cultures. These are climatic conditions, the possible presence of insects or diseases, imperfect physical conditions in the soil and subsoil, such as hardpan, high water-table, shallowness of the soil, lack of ventilation and aëration, poor moisture supply, etc., any of which might cause intense suffering on the part of the plant. All of these must be considered before alkali can be charged with the trouble. Then when we come to consider the alkali itself we are met by its complexity and variability in composition, and it is only by a process of elimination that definite conclusions can be reached. It is easy enough to make tables showing the highest amount of each salt thus far found to be tolerated by the different cultures, but it is often very difficult to say positively that the death or suffering on the part of a culture is due to the presence of a certain salt, for other salts are always present in large or small amounts. When, however, the amount of one of the constituents is far below, and that of another is much above the amount tolerated by the plant elsewhere, it is quite safe to conclude that any distress on the part of the plant is due to the latter; provided, of course, that physical conditions of the soil are favorable to the life of the plant. In some cases where the amount of a certain salt was enormous, there could be but little doubt that the suffering of the plant was due to it; but the *lowest* limit of such intolerance is as yet undetermined.

The following tables give some of the results obtained by the analysis of the alkali soils bearing various crops, the effort being to select such as were typical of the effect and non-effect of alkali upon the growth. While the samples were actually examined for each foot in depth, it has been thought best for this bulletin to give only the average of the entire column as a whole, especially for the orchard trees whose roots penetrate deeply into the soil when free to do so. For smaller cultures, whose roots are chiefly found in the upper two feet of the soil, we give results for each of the two feet and the total found in four feet; otherwise the results would prove very puzzling and conflicting. The results are briefly discussed for each culture and a comparative summary of maximum tolerance is given in tabular form at the end of the bulletin.

We do not present all of the soils whose examinations have been made, but only those of most importance in showing the maximum of tolerance for the various crops; as already stated, many alkali spots were examined that gave no definite results, and are therefore omitted from the statement.

It should be said that the limits of tolerance thus far shown are probably for the most part too low, and that further investigation will without doubt greatly enlarge these limits on the part of some of the crops enumerated. We propose to continue the work, and with the aid of farmers living in alkali regions we hope to greatly add to the number and value of observations already made.

RESULTS OF INVESTIGATION.

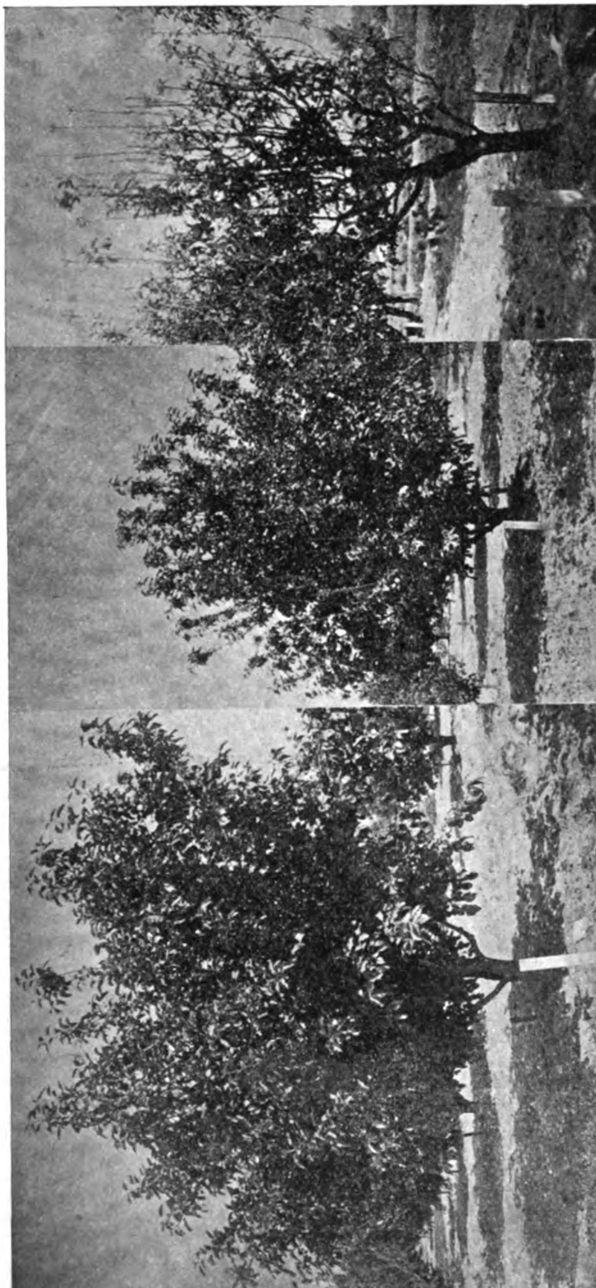
ORCHARD TREES.

Analyses of orchard soils have been made from a number of localities, but those given in the tables are mostly from the Tulare substation. It will be seen that the list comprises the chief orchard crops of California; and while most of them are represented in their extremes of good and poor growths, there are a few which could only be found in a state of good growth, and in what seemed to be strong alkali.

Alkali in Soils of Orchards.

Trees.	Condition	Per Cent in Soil. Sulfates	Carbonate	Chlorid	Total	Pounds per Acre; 4 ft. depth. Sulfates (Glauber Salt)	Carbonate (Sal Soda)	Chlorid (Common Salt)	Total Alkali
ALMONDS—									
Tulare	Good	.142	.009	.015	.166	22,720	1,440	2,400	26,560
APPLES—									
Tulare—Red Bietigheimer	Good	.089	.004	.008	.101	14,240	640	1,240	16,120
Duchess	Poor	.117	.008	.021	.146	18,760	1,200	3,320	23,280
Jonathan	Poor	.029	.005	.007	.041	6,840	1,080	1,720	9,640
APRICOTS—									
Tulare	Good	.054	.003	.006	.063	8,640	480	960	10,080
Tulare	Affected	.214	.011	.021	.246	34,240	1,760	3,260	39,260
FIGS—									
Tulare—Osburn's Prolific	Good	.153	.007	.005	.165	24,480	1,120	800	26,400
California Black	Good	.068	.005	.001	.074	10,880	760	160	11,800
LEMONS—									
La Mirada	Good	.028	.003	.005	.036	4,480	480	800	5,760
La Mirada	Stunted	.032	.003	.009	.044	5,120	480	1,440	7,040
La Mirada	Dead	.039	.007	.012	.058	6,240	1,120	1,920	9,280
OLIVES—									
Tulare—Nigerina	Good	.192	.018	.042	.252	30,640	2,880	6,640	40,160
Regalis	Good	.126	.017	.021	.164	20,160	2,640	3,360	26,160
La Mirada	Good	.025	.015	.014	.054	4,000	2,400	2,240	8,640
La Mirada	Stunted	.271	.029	.074	.374	43,360	4,640	11,840	59,840
Kern City . . . 5 feet	Dead	.245	.010	.152	.407	49,000	2,000	30,400	81,400
ORANGES—									
Tulare	Fair	.062	.024	.021	.107	9,840	3,840	3,360	17,040
Chino	Good	.155	.012	.015	.182	18,600	1,440	1,800	21,840
Corona	Fair	.018	.008	.002	.028	2,920	1,280	360	4,560
Corona	Poor	.028	.013	.011	.052	4,520	2,000	1,800	8,320
Corona	Poor	.029	.010	.015	.054	4,720	1,680	2,520	8,920
PEACHES—									
Tulare	Best	.060	.004	.006	.070	9,600	680	1,000	11,280
Tulare	Poor	.084	.007	.015	.106	13,400	1,160	2,440	17,000
Hanford	Poor	.088	.002	.070	.160	14,080	320	11,200	25,600
PEARS—									
Tulare	Best	.111	.011	.009	.131	17,800	1,760	1,360	20,920
Tulare	Poor	.239	.013	.009	.261	38,280	2,080	1,360	41,720
PLUMS—									
Tulare	Very poor	.140	.011	.014	.165	22,360	1,760	2,120	26,240
PRUNES ON MYROBALAN—									
Tulare	Good	.058	.009	.008	.075	9,240	1,360	1,200	11,800
MULBERRY—									
Tulare	Good	.021	.001	.014	.036	3,360	160	2,240	5,760

Almonds.—The almond trees of the Tulare substation are isolated from the other orchard growths and were all in a healthy condition and



Red Bietigheimer. Duchess of Oldenburg. Jonathan.

PLATE 2. APPLE TREES.

loaded with fruit at the time visited. The varieties were the I X L and Harriott's Seedling. The soil samples were taken from midway between the trees to a depth of four feet. No trees have been found whose poor condition could be attributed to alkali; hence, the greatest limit of tolerance in the almond has as yet not been ascertained, but is clearly above 2,000 pounds of carbonate of soda and 3,000 pounds of common salt per acre four feet deep.

Apples.—The only observations made on the apple were at the Tulare substation in 1900. The tree is quite sensitive to alkali salts, and their effect on the foliage of the tree was very marked, as is shown in the accompanying illustration (plate 2) from a photograph made at the time the soil samples were taken. The newer limbs of the tree appear as canes with a tuft of leaves at the upper end, instead of being covered with foliage throughout, as is also shown in the photograph. Samples of soil were taken to the depth of four feet under the Duchess of Oldenburg, which was in very poor condition, with no fruit, and whose top was losing its leaves; the Jonathan, also very poor, and the Red Bietigheimer, which was in excellent condition. The results of the examination make it clear that while the apple will tolerate the presence of 14,000 pounds of sulfates, 650 of carbonate of soda, and 1,200 of common salt, it is injured by 1,200 pounds of carbonate and 3,000 pounds of common salt per acre distributed through four feet depth. The Jonathan seems to be more sensitive than the Duchess.

Apricots.—The trees selected as representing the best and the worst condition respectively were grown upon their own stock. The differences between the two were very marked, in the greater height and full foliage, large leaves, and vigorous growth in the one, and the thinner foliage, smaller and blighted leaves, new leaves in clusters at end of limb, and evident poor health in the other; some twigs had lost their leaves entirely. The accompanying photograph (plate 3) shows these effects. The results of the examination of the respective soils show that while the total alkali and that of each salt are greater in the soil of the poor tree, and that to either of these might be attributed the trouble, it is more than likely that either the sulfate or the common salt is the true cause; for their amounts are excessive, while that of the carbonate is lower than what is tolerated by most cultures.

Figs.—The examinations for fig trees gave results that were not of special importance, for the amounts of common salt and carbonate of soda present in the soil were not very large. The tree easily tolerated as much as 25,000 pounds of glauber salt and 1,100 pounds of carbonate of soda per acre in four feet.

Lemons.—The lemon seems to be the least tolerant of all of the fruit trees, for it was stunted by only 1,440 pounds of common salt per acre

Good. Yielding to alkali.

PLATE 3. APRICOT TREES.

distributed through four feet depth, and was killed by 1,900 pounds combined with 1,900 pounds of carbonate of soda. Its endurance of carbonate of soda has not been ascertained. The trees examined were from an orchard near La Mirada, Los Angeles County. In one part of the tract the trees were doing well, the soil showing only comparatively small amounts of alkali salts. In another the trees were stunted, and an examination showed no signs of disease, the trouble being evidently due to the alkali. In the lower part of the orchard, at the end of the irrigation furrow, where water was caught from run-off during the past five or six years, thus permitting the alkali to accumulate, the trees

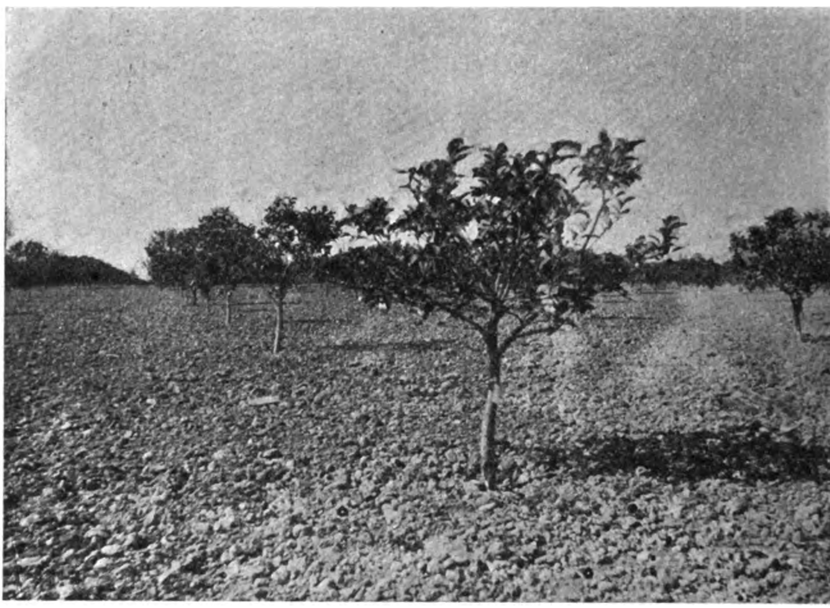


PLATE 4. Lemon Orchard Affected by Alkali; Before Deep Irrigation.

have during the past year showed signs of disease, and many have died. The alkali in this land is much in excess of that where the trees were merely stunted, thus indicating this excess as the cause of trouble.

The manager of the orchard, Mr. S., told the writer that he had by a system of subirrigation caused water to dissolve the salt and carry it deeply into the ground out of reach of the feeding roots of the trees, its rise to the surface being prevented by cultivation of the soil. The result appeared in the greatly improved condition of the trees, which in eight or ten months after this treatment seem to have almost recovered their vigor. Photographs of the trees before (plate 4) and after (plate 5) treatment were taken by Mrs. S., and are reproduced in the accompanying engravings.

Oranges.—From the culture experiments at Tulare substation it would seem that oranges do fairly well in the presence of 3,840 pounds of carbonate and 3,360 pounds of common salt per acre in four feet depth, or a total of 17,040 pounds of alkali. The examinations at Corona seem to contradict this, for there the trees suffered in 1,680 pounds of carbonate and 2,500 pounds of common salt. The explanation is that the conditions surrounding the trees were different, for at Tulare a detailed examination shows that the salts were distributed through the four feet of soil quite evenly, while at Corona the common salt was all contained in the first two feet. Then, too, at Tulare the

PLATE 5. THE ABOVE ORCHARD AFTER ALKALI WAS DRIVEN DOWN BY DEEP IRRIGATION, FOLLOWED BY CULTIVATION.

roots of the tree were by proper culture encouraged to send their feeding roots to a depth of seven or eight feet below the surface, while at Corona the system of shallow furrow-irrigation so much practiced in Southern California had compelled the roots to remain within a short distance of the surface of the soil to secure necessary moisture, and hence the salt concentrated near the surface could act with greater energy.

Thus is emphasized the importance of the oft-repeated injunction to so use irrigation water and cultivation as to permit the roots of trees to follow their natural tendency of penetrating deeply into the soil. Had the salts in the Corona soils been distributed through a greater depth the trees would doubtless have withstood the effects of the alkali much longer. In fact, since the publication of the Station Report of 1898, the orchardists of Corona have very greatly improved their groves by this treatment and the use of pure water; and the particular orchard there shown as typical of the effects of alkali has now recovered its vigor and foliage.

Mulberry.—The extreme tolerance of the mulberry could not be ascertained, as the few trees were all in excellent condition with no more of common salt or of other salts than is tolerated by other trees.

Olives.—The olive trees of the Tulare substation were all in good condition when visited, though some stood in soils quite highly charged with alkali salts. Of those represented in the table the Præcox was in a sandy soil, while the Regalis and Nigerina were in loams. Samples of soil were also sent to this office from an olive orchard near La Mirada, Los Angeles County, by the manager. One lot of samples was from the high part of the orchard, where the trees were large and healthy; the other lot was from lower land, where the trees were six years old, but stunted (four feet high); the same treatment had been given the trees in both cases. Another series of samples were sent by the manager of an olive orchard near Kern City, Kern County, in which the trees were suffering. The results of examination are shown in the table.

The olive tree is clearly immune to as much as 3,000 pounds of carbonate of soda (black alkali) and 30,000 pounds of glauber salt per acre in four feet, and the limit of tolerance will probably be found to be much above those figures.

The tolerance for common salt is above 6,000 pounds per acre in four feet, for the Nigerina did well in about that amount. At La Mirada the trees were stunted in presence of 11,800 pounds, and killed in an orchard near Kern City where there was 19,500 pounds in four feet depth and 30,400 pounds in five feet. At Kern City, however, the greater part of the alkali was contained in the soil below a depth of two feet, and had the examination gone deeper than five feet there would doubtless have been found in all about 50,000 pounds of common salt in a total of over 100,000 of alkali salts.

The following method of planting the trees adopted by the owner of the latter orchard has enabled them to secure a good growth before the roots felt the effects of the alkali, and illustrates the importance with some cultures of forcing the alkali down to quite a depth by the use of plenty of water and allowing the plant to secure a foothold:

The holes for the trees are made three feet deep and as wide, several months before planting; near planting time they are partially filled with good soil and filled with water. When the water has seeped down, the holes are filled with top soil and the trees planted. The alkali is thus washed beyond the depth of the roots. There is hardly a doubt but that if there had not been such an enormous amount of alkali in the lower four or five feet the trees would have successfully resisted its effect on the roots.

Peaches.—The trees at the Tulare substation were in part in fairly good and in part in poor condition, and samples of soils were taken from the best representatives of each. Both were on peach stock, and the difference in appearance was in smaller leaves and general unhealthy growth, due to either the common salt or carbonate as shown in the table.

From the region of Hanford, Kings County, peach trees were reported as being in bad condition; and through the kindness of Mr. Motheral, samples were sent us for examination. "Many of the trees in this orchard are troubled with the supposed disease known as 'little peaches,' but in this particular place the trees had been cut back and were putting out new growth which was yellowish in color, evidently due to some trouble in the soil. The water level is usually at a depth of four or five feet below the surface, though after heavy rains it often rises to within three feet. The land of the region is naturally highly productive, and the trouble can only come from the effect of the water on the roots, or from alkali in the soil." The examination of this soil shows the presence of an enormous amount (11,200 pounds) of common salt in the four feet, to which doubtless the dying of the trees must be attributed.

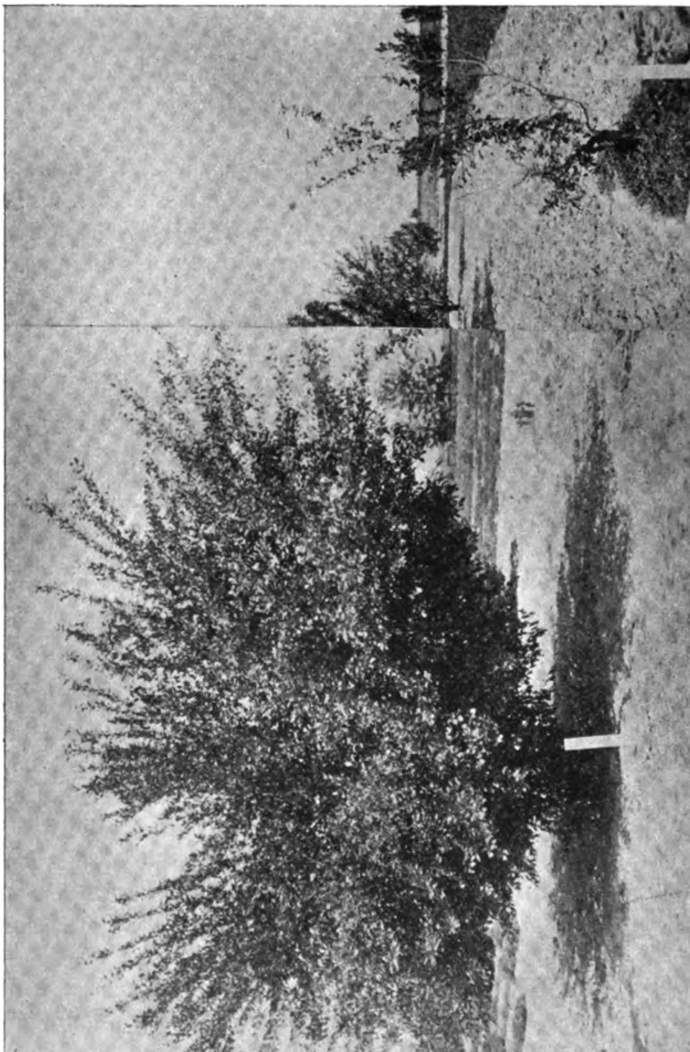
The results obtained at Tulare make it probable that the limits of alkali tolerated by peach trees may be placed at 10,000 pounds of sulfates, 750 of carbonate, and 1,200 of common salt per acre in four feet depth.

Pears.—The effect of alkali upon the pear was noticed only in the orchard of the Tulare substation, where quite a large block of land is given to its culture. Through the central part of this lies a belt of alkali which has seriously injured some of the trees, the leaves turning yellow or blackening at the tips as shown in the photograph on the title-page of this bulletin, and others being killed. On either side of this belt the trees are in good condition and bear well. Samples of soil were taken under LeConte and Keiffer trees which were yielding to alkali, showing the yellow leaves with blackened tips; they had no fruit.

The samples from the "best trees" are from the northern part of the pear block. The trees are Kennedy varieties and were planted long before the alkali had encroached on them; so that their roots have escaped attack, although the amount of alkali is greater than under the other trees.

The results would seem to show that while the pear can tolerate as much as 1,400 pounds of common salt and 1,800 pounds of carbonate per acre in four feet, it is seriously affected by 38,000 pounds of the sulfate, for it is hardly possible that an addition of 320 pounds of carbonate in the four feet per acre would produce the damage.

In another locality the trees were killed in land whose surface soil contained 4,600 pounds of carbonate and 18,000 pounds of common salt in a total of 62,000 pounds.



Prune on Myrobalan stock. Plum on plum stock.

PLATE 6. PRUNE AND PLUM.

Plums.—The Robe de Sergent plum at the Tulare substation is on its own stock and suffering very severely from alkali, as shown in the photograph on plate 6. The tree was dwarfed, and the limbs were losing their leaves. The amount of alkali in this case was not large, only 26,240 pounds, and amounts of the carbonate and common salt were also comparatively small. This plum, therefore, is one of the most sensitive of trees to the effects of alkali salts.

Prunes.—Prune trees, if grown on Myrobalan stock, should be highly tolerant of alkali salts, for that stock is a native of Asia Minor, where alkali abounds. We have thus far been unable to secure samples of soil where the trees showed the effect of alkali. At the Tulare substation the amount in their soils was only about 12,000 pounds per acre in four feet, and of this only 1,360 was of carbonate and 1,200 of common salt. It is said that at Hanford, Kings County, the prune flourishes in alkali soils where the peach is severely affected; we may therefore place the power of tolerance at quite high figures for common salt at least. If it be true that this fruit tree can withstand a very large amount of common salt it will prove of great value in alkali regions, for the carbonate of soda part of alkali can easily be neutralized by gypsum.

Walnuts.—Samples of soil were sent from an orchard near Anaheim, Orange County, in which "walnut trees have been planted, but they soon died and the roots rotted very quickly, while outside of this spot they do exceptionally well." The examination of the samples showed the presence of 18,000 pounds of common salt and about the same amount of sulfates per acre in four feet depth.

VINEYARDS.

A large part of the Tulare substation tract is occupied by grapes representing about one hundred and fifty varieties. Alkali spots have appeared here and there (by rise from below through use of irrigation water), and in several instances the salts have seriously affected the vines. The results of the examination of the soils forcibly illustrate the fact that the susceptibility of the vine varies according to variety, and that while some are tolerant of very large amounts of carbonate of soda and common salt, others succumb to the effect of far less of each.

Alkali in Vineyard Soils.

Grapevines.	Condition	Per Cent in Soil.				Pounds per Acre: 4 ft. depth.			
		Sulfates	Carbonate	Chlorid	Total	Sulfates (Glauber Salt)	Carbonate (Sal Soda)	Chlorid (Common Salt)	Total Salts
Persian	Lived	.144	.063	.077	.284	17,290	7,550	9,640	34,480
Persian	Barely lived	.072	.214	.005	.291	8,670	25,620	640	34,930
Persian	Died	.205	.311	.091	.607	24,640	37,280	10,890	72,810
Sauvignon vert	Thrifty	.255	.003	.028	.286	40,800	480	4,480	45,760
Chasselas	Thrifty	.247	.005	.031	.283	39,520	800	4,960	45,280
Boal de Madeira	Thrifty	.188	.004	.028	.220	30,080	640	3,680	34,400
Mission Grape	Thrifty	.160	.030	.006	.196	25,640	4,760	960	31,360

Alkali in Vineyard Soil—Continued.

Grapevines.	Condition	Per Cent in Soil. Sulfates	Carbonate	Chlorid	Total	Pounds per Acre; 4 ft. depth. Sulfates (Glauber Salt)	Carbonate (Sal Soda)	Chlorid (Common Salt)	Total Salts
Mission Grape	Not growing	.416	.010	.006	.432	66,520	1,560	920	69,000
Trousseau	Thrifty	.170	.007	.019	.196	27,200	1,120	3,040	31,360
Verdal	Thrifty	.160	.003	.023	.186	25,600	480	3,680	29,760
Teinturier mâle	Thrifty	.150	.003	.029	.182	24,000	480	4,640	29,120
Thompson's Seedless	Thrifty	.134	.003	.013	.150	21,480	520	2,040	24,040
Burger	Thrifty	.120	.005	.090	.215	19,200	800	1,440	21,440
Meunier	Thrifty	.094	.010	.006	.110	15,040	1,600	960	17,600
Meunier	Suffered	.209	.007	.012	.228	33,440	1,120	1,920	36,480
Meunier	Died	.207	.007	.018	.232	33,120	1,120	2,880	37,120
Flame Tokay	Thrifty	.070	.045	.004	.119	11,200	5,560	600	17,360
Flame Tokay	Not growing	.116	.031	.005	.152	18,560	4,960	800	24,320
Pedro Jimenes	Thrifty	.067	.023	.004	.094	10,680	3,600	600	14,880
Pedro Jimenes	Not growing	.110	.029	.006	.145	17,600	4,640	960	23,200
Negro	Thrifty	.081	.012	...	.093	12,960	1,920	...	14,880
Negro	Not growing	.206	.022	.005	.233	33,000	3,480	800	37,280

Of the above fourteen varieties of grapes the Persian withstands the effects of alkali the best, especially of carbonate of soda and common salt. There seems but little doubt that it would flourish in soils containing one tenth of one per cent of common salt, or an equivalent of 16,000 pounds per acre in four feet. The tolerance for carbonate of soda is great, for in the presence of more than two tenths of one per cent, or 25,600 pounds per acre, it managed to keep alive, thus indicating a true tolerance of probably 15,000 or perhaps 20,000 pounds per acre in four feet.

For other varieties the limits vary greatly, some being more sensitive to the several salts than others. The Sauvignon vert and Chasselas appear to be more tolerant of glauber salt and common salt than were other varieties, for they made a fine growth in the presence of about 40,000 pounds of sulfate and 5,000 pounds of common salt per acre in four feet. The Teinturier mâle would probably be their equal, for its amount of common salt was nearly the same.

The amount of carbonate of soda (black alkali) which the grape is able to withstand was in a few cases fairly well shown, especially where the common salt was low. Thus the Flame Tokay grew well in soil with 5,500 pounds of carbonate, and the Mission in presence of 4,700 pounds. Unfortunately the sulfate of soda is also very largely present and influences the results; thus the Flame Tokay was clearly killed by the 18,560 pounds of sulfate in conjunction with a large amount of carbonate. And yet a number of other varieties easily grow in twice this amount of sulfate.

The Meunier is very sensitive to alkali salts and succumbed to small amounts of carbonate and common salt combined with 33,000 pounds of sulfate, which was less than that in which many other varieties grew well. As a rule, grapevines seem to easily withstand 30,000 pounds of sulfate, and 5,000 of carbonate and common salt each.

NOTE ON THE EFFECT OF ALKALI SALTS UPON THE GROWTH OF GRAPEVINES AND ON THE COMPOSITION OF GRAPES.

By A. M. DAL PIAZ.

The injurious effect of strong alkali salts upon fruits in general is well known; grapevines are no exception, for strong alkali will kill them and weaker alkali affects them proportional to its strength and composition. The effect of alkali upon the vine and its product is a matter of economic interest, and an investigation on this subject was begun by the writer upon vines at the Tulare substation in 1900, and the results are here briefly presented; analyses of the alkali soils in which the vines were growing were made in the station laboratory by Mr. Snow.

The vines of the Burger, Sauvignon vert, and Trousseau were growing partly in weak and partly in strong alkali soils. The grapes of each variety did not show any marked difference in size, excepting where growing in strong alkali; but the vines themselves were there considerably shorter in growth, and therefore the bunches and berries were smaller and more advanced in maturity.

The Meunier is growing about an alkali spot, partly on weak alkali and showing a healthy growth, partly on stronger alkali and showing a shorter growth, and were killed on still stronger alkali. The following table gives the composition of these alkali soils, to which is added the results of examination of the sugar, acid, ash, and tannin in the grapes grown respectively on the weak and the strong alkali:

Pounds of Alkali Salts per Acre in Four Feet Depth.

	Sauvignon Vert.		Burger.		Trousseau.		Meunier.		
	Weak Alkali.	Strong Alkali.	Weak Alkali.	Strong Alkali.	Weak Alkali.	Strong Alkali.	Weak Alkali.	Strong Alkali.	Strong Alkali.
Sulfates	21,760	40,800	19,200	21,280	20,480	27,200	15,040	33,440	33,120
Carbonate	1,280	480	800	640	480	1,120	1,600	1,120	1,120
Chlorid	4,480	4,480	1,440	1,440	4,000	3,040	960	1,920	2,880
Total	25,520	45,760	21,440	23,360	24,960	31,360	17,600	36,480	37,120

Composition of Grapes: August 24, 1900.

Sugar %	26.39	24.43	20.24	20.60	25.75	24.64	26.86	24.53	Vines killed.
Acid %	.38	.65	.71	.59	.47	.50	.45	.50	
Ash %	.28	.37	.33	.33	.49	.36	.36	.40	
Tannin %	....	....	....	....	.147	.155	.159	.167	

The four grape varieties of the above table, grown on weak and strong alkali soils, show differences in growth and grape composition remarkably well. The sugar content seems to have throughout the tendency of decreasing with increasing strength of the alkali salts; this is shown by the varieties of Sauvignon vert, Trousseau, and Meunier. The Burger does not show this, because of the nearly equal strength of alkali in both soils.

The total acidity of the grapes seems to be less influenced by variations in strength of alkali; three of the varieties show an increase with increased alkali. This increase of total acidity and decrease of sugar content in strong alkali soils is doubtless caused by the diminished vigor and poor growth of the vines in such soils.

The analysis of the red wine varieties, Trousseau and Meunier, indicates a slight rise of tannin with increasing strength of alkali in the soils; this increase is, however, too small for drawing any final conclusions.

The above results seem to indicate some important facts worthy of being made known. First of all, the quality of wine grapes of the Tulare region does not decrease with increasing strength of alkali in the soil, at least up to a certain limit of total salts. The increase of total acidity of the grapes grown in stronger alkali is of special value in the making of sound wines in similar localities, while the decrease of sugar content secures at the same time a wine not too alcoholic. The practical wine-making experiments with Tulare grapes, undertaken by the Agricultural Experiment Station, have indicated this fact: they have shown that sound, light table-wines, excellent for blending purposes, or as light neutral wines for consumption, could be made of grapes grown on such alkali soils.

The growing of raisin grapes in strong alkali soils cannot be recommended, as the tendency of the sugar content to decrease with increasing alkali results in the production of an inferior raisin.

GRAIN.

Observations have been made for a number of years on the grains of the experiment station at Tulare, and it has been proven that they will grow in alkali soils where there is an absence of so much carbonate of soda as would corrode the tender crowns of the roots. Some of the results were published in the Report for 1894–5, and are included in the table below:

Alkali Salts in Grain Lands.

	Condition.	Per Cent in Soil.				Pounds per Acre; 4 ft. depth.			
		Sulfates....	Carbonate...	Chlorid.....	Total.......	Sulfates (Glauber Salt)....	Carbonate (Sal Soda)	Chlorid (Common Salt)....	Total Salts...
Wheat—									
Tulare—Russian, Plot 12	3 feet high..	.064	.006	.007	.077	10,240	1,000	1,120	12,360
	20 in. high..	.095	.009	.004	.108	15,120	1,480	680	17,280
	6 in. high...	.213	.023	.017	.253	34,120	3,640	2,680	40,440
Plot 16	Good	.089	.005	.007	.101	14,160	720	1,160	16,040
	Medium	.126	.001	.025	.152	20,120	200	3,920	24,240
	Very poor ..	.289	.002	.054	.345	46,160	360	8,680	55,200
Armona................	Dead	.144	.026	.034	.204	23,040	4,180	5,360	32,580
Gluten Wheat—									
Tulare	4 feet high..	.027	.019	.001	.047	4,240	3,000	200	7,440
	Good	.131	.012	.009	.152	20,960	1,880	1,480	24,320
Barley—									
Tulare	4 feet high..	.063	.074	.015	.152	10,720	12,170	2,630	25,520
Tulare	Yield 1 ton.	.150	.028	.064	.242	12,020	2,200	5,100	19,320
Tulare	Dead	.061	.117	.020	.198	9,760	18,720	3,200	31,680
Hynes	Dead	.076	.020	.056	.152	12,160	3,200	8,960	24,320
Rye—									
Tulare	....	.061	.006	.011	.078	9,800	960	1,720	12,480

Wheat.—The Russian wheats, received from the U. S. Department of Agriculture, were planted in plot 12 of the Tulare substation. The rows extended across an alkali spot and presented heights corresponding to the strength of alkali; that in the soil of strongest alkali being about six inches, that at the end of the rows where alkali was weak having a height of several feet. Samples of soil were taken at the two extremes and at a medium point, as shown in the table above. The gradation in size seems to follow a similar gradation in amount of carbonate of soda, in inverse order, the smaller the carbonate the higher the stalk of wheat, 1,480 pounds being about the limit of tolerance. The amount of common salt was rather small to influence the results with the Russian wheats, but on plot 16 with other varieties it seemed to be the chief agent, the grain suffering more and more as the salt increased, a medium height occurring where there was 3,920 pounds per acre in four feet depth. The plot on which this wheat was planted is quite sandy and deep, with a thin incrustation of alkali on the surface, especially where the grain was poorest.

On plot 16, and in fact on all of the northwest corner of the station which is given to wheat, the ground was covered with a thick and white crust of alkali salts, even where the grain was several feet in height. The soil here is more of a loamy nature than that of plot 12, and was once a black alkali spot utterly bare of vegetation, but has been reclaimed by applications of gypsum.

The sample from Armona, Kings County, is from land once included in Tulare Lake region, but long left dry by the drying-up of the lake. Here the wheat died in presence of 4,180 pounds of carbonate of soda and 5,360 pounds of common salt, each being above the probable limits of tolerance.

From the results thus far obtained we would judge that wheat should do well in deep and loose soils having not more than 20,000 pounds of total alkali, of which there is not more than 1,200 pounds each of carbonate of soda and common salt per acre in four feet depth.

Alfalfa. Gluten Wheat. Goat's Rue.

PLATE 7. GRAIN AND FODDER PLANTS; TULARE SUBSTATION.

Gluten Wheat.—Gluten wheat at Tulare attained a splendid growth in presence of 24,300 pounds of alkali, of which nearly 1,500 pounds was common salt. In another spot, as shown in the photograph (plate 7), it also grew well in as much as 3,000 pounds of carbonate of soda per acre in four feet depth.

Barley.—The fact is shown in the table that barley grew to a height of four feet in land containing more than 12,000 pounds of carbonate of soda per acre in four feet, and produced one ton of hay per acre in presence of more than 5,000 pounds of common salt. It is therefore better adapted to alkali land than is wheat. It was killed by 18,720 pounds of carbonate of soda, as would happen with most plants. At Hynes, in Los Angeles County, it was killed by 8,960 pounds of common salt, 3,000 of which was in the upper six inches.

Rye.—A fair test has not been given to rye as to its capabilities of withstanding alkali salts, for the amount found in the soil in which it was growing at the Tulare substation was very small.

LEGUMES AND FODDER PLANTS.

Special efforts have been made to obtain samples of soil from where these plants were growing well in strongest alkali and where they were severely affected by it, but we have been only partially successful. The Tulare substation has naturally furnished most of them, and further experiments and planting of those cultures which do not appear in the table will have to be made.

Alkali in Soils of Forage Crops.

	Per Cent in Soil.				Pounds per Acre: 4 ft. depth.			
	Sulfates…	Carbonate…	Chlorid…	Total…	Sulfates (Glauber Salt)…	Carbonate (Sal Soda)…	Chlorid (Common Salt)…	Total Salts…
ALFALFA (young)—								
Tulare, 1 mi. N.E. Good…1st foot	.077	.006	……	.083	3,080	240	……	3,320
2d foot	.060	.004	.010	.074	2,400	160	400	2,960
Total in 4 feet	.059	.008	.004	.071	9,440	1,280	680	11,400
1 mi. S.W. Dead…1st foot	.145	.016	.010	.171	5,800	640	400	6,840
2d foot	.103	.010	.010	.123	4,120	400	400	4,920
Total in 4 feet	.077	.011	.007	.095	12,280	1,680	1,080	15,040
1 mi. S.E. Dead…1st foot	.230	……	.026	.256	9,200	……	1,040	10,240
2d foot	.084	……	.014	.098	3,360	……	560	3,920
Total in 4 feet	.101	……	.013	.114	16,160	……	2,080	18,240
Chino—Good……1st foot	.104	.051	……	.155	4,160	2,040	……	6,200
2d foot	.071	.008	.005	.084	2,960	320	200	3,480
Total in 2 feet	.088	.030	.003	.121	7,000	2,360	200	9,560
Fair……1st foot	.241	.014	.019	.274	9,640	560	760	10,960
2d foot	.037	.017	……	.054	1,480	680	……	2,160
Total in 2 feet	.139	.016	.010	.165	11,120	1,240	760	13,120
Killed……1st foot	.289	.022	.009	.320	11,560	880	360	12,800
2d foot	.023	.022	.005	.050	920	880	200	2,000
Total in 2 feet	.156	.022	.007	.185	12,480	1,760	560	14,800
ALFALFA (4 years old)—								
Yuma—Splendid……4 feet	.462	.009	.027	.498	73,960	1,400	4,400	79,760
6 feet	.427	.009	.024	.460	102,480	2,080	5,760	110,320
TURKESTAN ALFALFA—Good…	.023	.014	.007	.044	3,680	2,240	1,120	7,040
LUPIN, EUROPEAN—Good……	.034	.017	.019	.070	5,440	2,720	3,040	11,200
Medium…	.168	.009	.047	.224	26,880	1,440	7,520	35,840
Failure….	.250	.004	.038	.292	40,000	640	6,080	46,720

Alkali in Soils of Forage Crops—Continued.

	Per Cent in Soil.				Pounds per Acre; 4 ft. depth.			
	Sulfates	Carbonate	Chlorid	Total	Sulfates (Glauber Salt)	Carbonate (Sal Soda)	Chlorid (Common Salt)	Total Salts
HAIRY VETCH—								
Plot 8—Fair .... 1st foot	.621	.014	.045	.680	24,840	560	1,800	27,200
2d foot	.616	.027	.011	.654	24,640	1,080	440	26,160
Total in 4 feet	.398	.016	.020	.434	63,720	2,480	3,160	69,360
Plot 12—Good .... 1st foot	.458	.003	.009	.470	18,320	120	360	18,800
2d foot	.162	.010	.014	.186	6,480	400	560	7,440
Total in 4 feet	.180	.010	.008	.198	28,840	1,640	1,280	31,760
Very poor .. 1st foot	1.178	.018	.138	1.334	47,120	720	5,520	53,360
2d foot	.220	.024	.032	.276	8,800	960	1,280	11,040
Total in 4 feet	.395	.025	.047	.467	63,120	3,960	7,480	74,560
BUR CLOVER—Good	.057	.113	......	.170	5,700	11,300	....	17,000
WHITE MELILOT—Good	.031	.003	.003	.037	4,920	480	440	5,840
GOAT'S RUE—Splendid	.068	.005	.001	.074	10,880	760	160	11,800
SORGHUM—Splendid	.387	.062	.061	.510	61,840	9,840	9,680	81,360
MODIOLA—Splendid ... 1st foot	.170	.119	1.021	1.310	6,800	4,760	40,860	52,420
JERSEY KALE—Plot 8 .. 1st foot	.854	.013	.009	.876	34,160	520	360	35,040
2d foot	.285	.009	.056	.350	11,400	360	2,240	14,000
Total in 4 feet	.322	.023	.019	.364	51,480	3,600	3,000	58,080
ESSEX RAPE—Plot 8 ... 1st foot	1.141	.011	.014	1.166	45,640	440	560	46,640
2d foot	.232	.023	.037	.292	9,280	920	1,480	11,680
Total in 4 feet	.391	.034	.015	.440	62,560	5,480	2,440	70,480
SALTBUSHES—								
Atriplex semibaccata	.785	.116	.078	.979	125,640	18,560	12,520	156,720
Atriplex pamparum	.047	.091	......	.138	7,560	14,600	....	22,240

Alfalfa.—As this is the most important of the fodder plants of the State, we have made special efforts to ascertain the limits of tolerance of the various salts of alkali, but have been largely disappointed, because of the fact that the amount varies according to the stage of growth of the plant. When young its roots are very tender and sensitive to the corrosive action of carbonate of soda, and being confined to the upper foot or two of the soil are fully within its reach. But when the roots are older and have penetrated deeply into the soil, the root-crown has become more corky and hardened and less sensitive, so that they are enabled to withstand a far larger amount of the alkali.

These facts are clearly shown in the results given in the table. From the country around Tulare Mr. Forrer, the foreman of the substation, obtained many samples of soil from alfalfa fields where the plant was growing and where it had died. The maximum amount of total alkali found to a depth of four feet where the plant was growing well was 11,360 pounds, in which there was very little common salt and 1,300 pounds of carbonate of soda; while a short distance from this, where the plant had died, there was about the same amount of total alkali, but containing 1,100 pounds of common salt and 1,600 pounds of carbonate. In the first case the carbonate was chiefly in the lower third and fourth feet, while where the crop was dead the carbonate was chiefly in the upper two feet.

At the substation farm near Chino the results were very similar; alfalfa made a fair growth in the presence of 1,240 pounds of carbonate, and was killed by 1,760 pounds in the upper two feet, the common salt being low and the sulfate high in both cases. It is also very worthy of note that on the same plot the plant grew splendidly with a larger amount of carbonate of soda (2,360 pounds), because nearly all of the salt was held in the upper foot of soil and hence probably above the feeding roots. There was only a trace of common salt here, and but little in the second foot.

The tolerance of young alfalfa may then be placed at about 1,200 pounds of carbonate of soda, 750 pounds of common salt, and 12,000 pounds of sulfate per acre in the upper two feet of soil. But when the plant is older and its roots become firmly fixed in the soil, penetrating it deeply and spreading out laterally, the limits of toleration far exceed the above figures, even to an extent almost beyond belief. This is largely due to the perfect shading of the ground, thereby preventing the rise of the alkali.

In the neighborhood of Yuma, alfalfa fields were seen by Mr. F. J. Snow (student assistant in the laboratory) to be strongly charged with alkali and yet to be in fine condition. He was told that four years were required in getting a full stand, but after that the plant grew luxuriantly, yielding seven cuttings per year. The amount and character of the salts in the soil are given in the table. From another field where the alfalfa was also growing luxuriantly Mr. Snow found similar amounts of alkali of quite nearly the composition given above, except that the total in the first foot was nearly 17,000 pounds (.424 per cent) instead of 15,000.

The plot of alfalfa growing near the gluten wheat at the Tulare substation, shown in the photograph (plate 7), left side, is on a soil containing 3,440 pounds of carbonate of soda; but this salt is chiefly held below the upper two feet of soil, thus giving the feeding roots freedom from its action. The rise of the alkali is prevented from evaporation by the dense shading of the foliage.

Professor Buffum, of the Wyoming Experiment Station, has found that alfalfa was killed in a total of .706 per cent of alkali in the surface foot, all except .041 per cent of chlorid being sulfates of soda and magnesia. This would be equivalent to 28,240 pounds of total alkali per acre-foot and 1,640 pounds of chlorid. He also found that it grew in .152 per cent of alkali in the surface foot, equivalent to 6,080 pounds per acre; but this is more than doubled in the Yuma soil, as shown in the table.

While, therefore, alfalfa is easily killed by alkali when young, it will tolerate as much as 6,000 pounds of common salt, 3,000 pounds of carbonate, and 102,000 pounds of sulfate in six feet per acre if it succeeds in getting a good start and in sending its roots below the surface of the soil; and especially if the greater part of the alkali be sulfates. It is therefore very essential that prior to sowing alfalfa the alkali salts should be leached downward from the surface by thorough irrigation, until the plant is old enough to resist their attack by the hardening of its root-crown.

The importance of thoroughly washing the alkali deeply into the soil before the seed is planted, and keeping it there by proper means until the foliage of the plant shades the soil sufficiently to prevent the rise of moisture and alkali, is well illustrated in fields in the region of Bakersfield, where alfalfa is now growing in soils once heavily charged with alkali. From one of these fields samples of soil were taken by us where the alkali was supposed to be strongest beneath the alfalfa, and also from an adjoining untreated alkali spot which was said to represent conditions before alfalfa was planted. The results are given in pounds per acre in four feet depth.

	Sulfates.	Carbonate.	Common Salt.	Total Alkali.
Alkali spot before alfalfa was planted ..	60,120	720	175,840	236,680
Alfalfa field; alkali washed down	14,400	...	1,040	18,640

In the natural alkali soil the salts are distributed downward, somewhat evenly, except that there are in the surface foot nearly 140,000 pounds of common salt, while in the alfalfa field the alkali salts are chiefly below the second foot. A closer examination would doubtless have shown the main body of alkali to have been washed down to six feet from the surface, or even deeper.

Too much emphasis cannot, therefore, be placed upon the importance of thus controlling alkali and keeping it below a depth of four or five feet.

Blue European Lupin.—The plot in which the lupins were grown has the greater part of its alkali within the upper two feet, while in that part where the lupins failed three-fourths of the common salt and the sulfates was held in the first foot itself. Both the common salt and sulfates seem to be responsible for the failure of the lupins, and it is clear that it cannot withstand more than 3,000 pounds of the former per acre; of the carbonate of soda it will tolerate as much as and perhaps more than 3,000 pounds per acre.

Hairy Vetch.—This fodder and green-manuring plant grew fairly well, reaching a height of about fourteen inches and bloomed in land containing 2,400 pounds of carbonate of soda, 3,000 pounds of common salt, and 63,700 pounds of sulfate per acre in four feet depth. As with the lupins and the vegetables, we find that here, too, the alkali occurs chiefly in the upper two feet of the soil, the common salt especially being in the first foot.

The very large amount of sulfates tolerated would show that when black alkali lands are neutralized with gypsum, the vetch will do fairly well, provided that common salt is not excessive. The limit of tolerance of the latter is a matter of doubt, for in the soil in which the vetch had a poor growth, there was present about 4,000 pounds of carbonate in addition to the 7,500 pounds of chlorid, and to either of these salts may have been due the bad effect. But in both of the soils examined the carbonate was chiefly in the second and third feet, and as its action is chiefly upon the tender root-crown at the surface of the soil, it would seem that the common salt was responsible for poor growth.

The foreman of the substation says that when young the vetch has a tendency to lie flat on the ground, so that on alkali soil it "burns" badly.

Bur Clover.—This clover was found growing luxuriantly in a small field adjoining the hot sulphur baths at Elsinore, in Riverside County. The soil received its water from a deep well, and was black from humus dissolved in the carbonate of soda of the alkali. An examination of the soil to thirty inches depth showed the remarkable toleration of 11,300 pounds of carbonate of soda per acre, thus giving it the rank of second in this regard among all the cultures examined. It doubtless is fully as tolerant as barley, which, aside from sorghum, heads the tolerance list of grasses thus far.

Argentine Saltbush (*Atriplex pamparum*).—The Inspector of Stations says of this saltbush: "*Atriplex pamparum* was sent to the Station by President Rocca of the Argentine Republic in 1897, together with seeds of other species of native saltbushes recommended to him by the botanists of that country. It has thus far proved to be the best species at Tulare substation, growing in alkali soil to a height of six feet and spreading fourteen feet in diameter. It is a browsing plant and is much liked by sheep. If kept down by feeding it furnishes much succulent food and is worth extensive trial." The examination of the soil where it grows luxuriantly shows the presence of 14,600 pounds of carbonate of soda, an amount nearly equal to that tolerated by the Australian saltbush.

Australian Saltbush (*Atriplex semibaccata*).—After a number of efforts we have finally found this fodder plant growing well in very strong alkali land, in which the several salts were in greatest amount within two feet of the surface. As it ranks high as a fodder plant suitable for alkali soils, we give the distribution of the salts in the soil-column:

Alkali Soil Growing Australian Saltbush.

	Per Cent in Soil.				Pounds per Acre.			
	Sulfates...	Carbonate..	Chlorid....	Total......	Sulfates...	Carbonate..	Common Salt......	Total.......
First foot..............	2.055	.284	.121	2.460	82,200	11,360	4,840	98,400
Second foot	.634	.089	.111	.834	25,360	3,560	4,440	33,360
Third foot.	.247	.042	.051	.340	9,880	1,680	2,040	13,600
Fourth foot	.205	.049	.030	.284	8,200	1,960	1,200	11,360
Total.....	3.141	.464	.313	3.918	125,640	18,560	12,520	156,720

These figures doubtless very nearly represent the maximum tolerance of the saltbush.

Very young plants have, however, suffered or languished in surface soils containing 9,000 pounds of carbonate of soda and 11,000 pounds of common salt, or a total of 31,000 pounds of alkali salts per acre; and have died when the soil was covered with an alkali crust containing 4.0 per cent of carbonate and 6.0 per cent of common salt. The plant came up easily from the seed in a soil containing 5,000 pounds of carbonate and 3,000 pounds of common salt per acre.

Sorghum.—At the Tulare substation sorghum grows luxuriantly in a small tract having a large amount of alkali, the surface often being black from humus held by the carbonate of soda. Irrigation is used on the crop, and there is therefore more alkali at the surface than at the third and fourth feet, although the dense mass of the crop shades the soil quite effectually. An examination of the soil shows a higher amount of alkali salts than in the soil of any other small culture thus far examined, viz.: 81,440 pounds per acre in four feet depth. The table of analyses shows that sorghum can easily tolerate as much as 10,000 pounds of carbonate of soda, the same of common salt, and 75,000 pounds of glauber salt per acre in four feet. At the time the examination was made, one half of the total glauber salt was in the upper foot, the greater part of the carbonate was in the second and third feet, while the common salt was quite evenly distributed through the four feet.

White Melilot.—Plants of this forage crop were found growing well near the "sump" in what was supposed to be very strong alkali, for the surface of the soil was crusted with it. But results of the examination show that there was less than 6,000 pounds of the salts per acre in four feet.

Goat's Rue (*Galega officinalis*).—A large patch of this was growing on plot 12 by the side of alfalfa and gluten wheat, and each of the three cultures were in splendid condition, the Goat's Rue being in dense mass and full growth, as shown on the right side of the photograph on page 26. Carbonate of soda and common salt were present in the soil in very small amounts, while of the sulfate there was nearly 11,000 pounds. The soil is sandy, and this amount is not excessive. The plant reached a height of about three and a half feet, and three cuttings were obtained.

Jersey Kale and Essex Rape.—These crops in the vegetable plot of the Tulare substation made a splendid start in strong alkali soil, preserving a dense growth, full of life and vigor. But each after reaching fourteen inches in height succumbed to the dryness and heat of the summer.

Modiola.—No further observations have been made on this forage plant than those given in the Report for 1896. It was grown by Mr. Leckenby near Bakersfield in soil containing more than 40,000 pounds of common salt and about 5,000 pounds of carbonate of soda per acre, in the surface foot. It is chiefly suited for permanent pasture, being of low growth and rooted at joints, so that it is not readily cut.

VEGETABLES AND GRASSES.

The vegetable plot 8 is located upon a strong alkali spot by the side of the main avenue of the station along whose side Australian saltbush grows luxuriantly. The alkali in this plot is of varying strength, being strongest along the roadside, where we usually find either failures or very weak vegetable plants. A general view of the plot with the cultures as seen in April, 1901, is given in the accompanying photograph (plate 8); a portion of the orchard, and long lines of saltbush are also seen on the left.

The alkali salts are mostly concentrated in the upper two feet of the soil, and their action is therefore more energetic than if distributed throughout four feet depth.

Alkali in Soils of Vegetables.

	Per Cent in Soil.				Pounds per Acre.			
	Sulfates	Carbonate	Chlorid	Total	Sulfates (Glauber Salt)	Carbonate (Sal Soda)	Chlorid (Common Salt)	Total Alkali
Sugar Beets—Fair.								
Tulare, Plot 8 ....1st foot	.541	.008	.009	.558	21,640	320	360	22,320
2d foot	.381	.006	.075	.462	15,240	240	3,000	18,480
Total in 4 feet	.329	.011	.034	.374	52,640	1,760	5,440	59,840
Plot 12 ......1st foot	.725	.003	.028	.756	29,000	120	1,120	30,240
2d foot	.337	.042	.009	.388	13,480	1,680	360	15,520
Total in 4 feet	.304	.025	.012	.341	48,560	4,000	1,920	54,480
Carrots—Fair.								
Tulare, Plot 8 ....1st foot	.357	.014	.023	.394	14,280	560	920	15,760
2d foot	.088	.010	.016	.114	3,520	400	640	4,560
Total in 4 feet	.156	.008	.015	.179	24,880	1,240	2,360	28,480
Radishes—In flower.								
Tulare, Plot 8 ....1st foot	1.012	.024	.047	1.083	40,480	960	1,880	43,320
2d foot	.137	.092	.009	.238	5,480	3,680	360	9,520
Total in 4 feet	.324	.055	.014	.393	51,880	8,720	2,240	62,840
Celery—								
Santa Ana—Good	.340	......	.080	.420	4,080	....	9,600	13,680
Failure	1.027	......	.276	1.303	123,240	....	33,120	156,360
Artichokes—Fair.								
Tulare, Plot 8 ....1st foot	.563	.010	.005	.578	22,520	400	200	23,120
2d foot	.234	.017	.009	.260	9,360	680	360	10,400
Total in 4 feet	.242	.017	.009	.268	38,720	2,760	1,480	42,960
Spinach and English Broad Beans—Failures.								
Tulare, Plot 8 ....1st foot	.832	.002	.195	1.029	33,280	80	7,800	41,160
2d foot	.163	.033	.030	.226	6,520	1,320	1,200	9,040
Total in 4 feet	.335	.012	.061	.408	53,600	1,920	9,760	65,280
Eleusine coracana—Failure.								
Tulare................1st foot	.812	.015	.019	.846	32,480	600	760	33,840
2d foot	.140	.046	.010	.196	5,600	1,840	400	7,840
Total in 4 feet	.255	024	.010	.289	40,720	3,800	1,560	46,080

Sugar Beets.—The sugar beets both on plot 8 and on plot 12 were planted close together, and were allowed to grow in that thick mass instead of being thinned-out to allow of development of root as when grown for their sugar content. The result was that while the tops were large and green, showing fair growth, the roots were about a foot in length with an average diameter of about an inch only. This small size may be largely attributed to the effect of the severe climate as well as to the crowding of the plants, for their leaves gave no indication of suffering from the alkali in the soil. The maximum of each salt tolerated by the plant in these two plots was 52,000 pounds of sulfates, 4,000 pounds of carbonate, and 5,400 pounds of common salt. The beets growing on plot 8 were very small, the largest weighing but about three ounces; a beet of that size should have a very high sugar content, but we find only 13.1 per cent and a purity coefficient of 80.

The largest beet on plot 12, in which there was less alkali than in plot 8, weighed about seven and one-half ounces and had a sugar content of 16.1 per cent and a purity coefficient of 81.

Previous results, given in the Annual Report of this station for 1895–6, show that the presence of 3,600 pounds of common salt in the soil seriously affected the sugar content of the beet; the above results lower this amount to 1,900 pounds, and even this seems to be above the limit in which the beet can attain good size and fair sugar-percentage.

Carrots.—The test was made on plot 8, and in presence of a total of 28,000 pounds of alkali, of which 2,300 was common salt; the plant

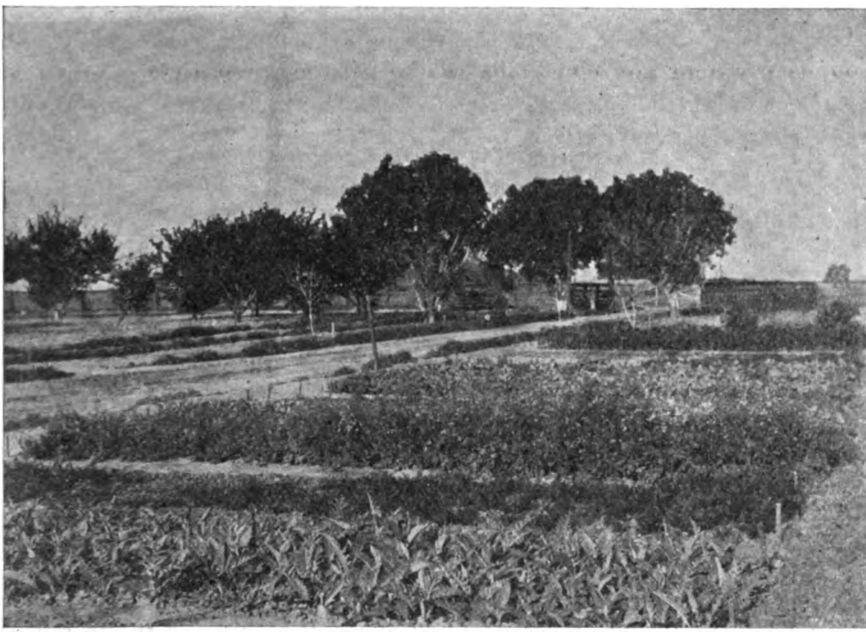


PLATE 8. VEGETABLE PLOT 8, TULARE SUBSTATION.

1. Artichokes.
2. Carrots.
3. Radishes in bloom.
4. Essex Rape and Jersey Kale.
5. Sunflowers and Sugar Beets.

Australian Saltbush in rows on left.

grew well, the roots having a length of about 10 inches, but a diameter of only about three fourths of an inch; the Foreman of the station, however, says that they were tender and of good flavor.

Radishes.—At the Tulare substation radish seed was planted in what seems to have been the strongest alkali of plot 8, and yet the seed germinated and the plant reached maturity, being in flower at the time the photograph and soil samples were taken. While the carbonate of soda was present in very large amount (8,700 pounds), it was chiefly held below the upper foot of the soil and therefore had no effect on the seed and young plant. Common salt was, on the contrary, chiefly in the upper foot, as was also the sulfate of soda. The radish, therefore, is capable of withstanding quite a large amount of alkali, if the carbonate is below the upper foot.

Globe Artichokes.—The amount of alkali in the soil where the artichokes were growing was about 43,000 pounds per acre, the sulfates being largely in the upper two feet, while more than half of the carbonate of soda and common salt respectively was below that depth.

Spinach and English Broad Bean.—These vegetables were grown on very strong alkali soils and were almost complete failures. A few scattering plants appeared where the carbonate of soda was only 2,000 pounds per acre and chiefly below the first foot, but they reached a height of only a few inches. The amount of common salt was about 9,000 pounds per acre.

Spelt and *Eleusine coracana* were both complete failures in the presence of 40,000 pounds of alkali.

The *Celery* fields in the alluvial lands around Santa Ana furnish good examples of the effects of alkali salts, except that no carbonate of soda was found in the samples kindly sent by Mr. Cole from spots where the plant was growing well and where the plant died. The results show that celery will easily tolerate as much as 10,000 pounds of common salt per acre, but is killed by 30,000 pounds.

Onions have grown well from the seed in the black alluvial soil of Leonis Valley, Mojave Plateau, Los Angeles County, which contained in the surface foot 400 pounds of common salt and 4,000 pounds of sulfate per acre.

Potatoes.—In the black alluvial soil of the Kern River near Bakersfield, which held in the first foot 18,400 pounds of alkali per acre, of which 4,000 was carbonate of soda and 6,800 common salt, two crops of potatoes were raised in a season, but their keeping quality was very poor. (Report 1896.)

GRASSES.

Ray grass at the Tulare substation grew well in a soil containing about 7,000 pounds of alkali per acre, which held no carbonate and very little common salt.

No observations on the tolerance of alkali on the part of grasses, and of crops not given above, that would increase the figures there shown, or which would throw more light on the subject, have been made since those published in the Report of 1896. These results show the amounts in the surface foot alone instead of in four feet depth; but at Chino, where the observations were made, the bulk of the salts is within the first foot.

Summarizing the data there given we have the following groupings of maximum amounts in the surface foot per acre in which the true grasses have thus far been found to do well:

Grasses Growing in Alkali Soils. Depth one foot.

CARBONATE OF SODA.

3,300 lbs. per acre: Japanese Wheat Grass, Barley.
2,500 to 3,000 lbs. per acre: Awnless Brome Grass, Schrader's Brome Grass, Sheep Fescue, Tall Fescue.
2,000 to 2,500 lbs. per acre: Egyptian Millet, Hard Fescue, Many-Flowered Paspalum, English Ray Grass, Rough-Stalked Meadow and Orchard Grass.
1,000 to 2,000 lbs. per acre: Bearded Darnel, Blue Grass.
600 to 1,000 lbs. per acre: Meadow Fescue, Many-Flowered Millet, Meadow Soft Grass, Italian Ray Grass.

COMMON SALT.

7,040 lbs. per acre: Barley.
3,000 lbs. per acre: Japanese Wheat Grass.
1,500 lbs. per acre: Schrader's Brome Grass.
900 lbs. per acre: Awnless Brome Grass, Sheep Fescue, Tall Fescue.
250 to 500 lbs. per acre: Many-Flowered Millet, Italian Ray Grass, English Ray Grass, Bearded Darnel, Orchard Grass.

MISCELLANEOUS.

There are a number of trees and other cultures growing upon the alkali soils of the Tulare substation that are of general interest, though in some cases the amount of alkali in their soils is low.

Miscellaneous Cultures and Trees.

Tulare Substation.	Condition.	Per Cent in Soil.				Pounds per Acre; 4 ft. depth.			
		Sulfates	Carbonate	Chlorid	Total	Sulfates (Glauber Salt)	Carbonate (Sal Soda)	Chlorid (Common Salt)	Total Alkali
Russian Sunflower, 1900	Good	.156	.008	.015	.179	24,880	1,240	2,360	28,480
Russian Sunflower, 1901	Good	.329	.011	.034	.374	52,640	1,760	5,440	59,840
Russian Sunflower	Poor	.226	.020	.010	.256	36,120	3,160	1,560	40,840
Washingtonia Palm	Large	.032	...	.006	.038	5,080	.....	1,000	6,080
Washingtonia Palm	Small	.082	.008	.007	.097	13,040	1,200	1,040	15,280
Date Palm	Large	.045	.018	...	.063	5,520	2,800	.....	8,320
Camphor Tree	Large	.033	.002	.009	.044	5,280	320	1,420	7,020
Oriental Sycamore	Large	.120	.020	.127	.267	19,240	3,200	20,320	42,760
Eucalyptus amygdalina	Large	.217	.017	.019	.253	34,720	2,720	2,960	40,400
Kölreuteria	Fair	.319	.062	.079	.460	51,040	9,920	12,640	73,600
Cañaigre	Fair	.057	.001	....	.058	9,160	120	80	9,360

Russian Sunflower.—The sunflower on plot 8 of the Tulare substation grew to a height of three feet and matured its seed in presence of about 60,000 pounds of alkali salts; the amount of carbonate of soda was, however, rather low, while that of common salt was high (5,440 pounds). When, however, the carbonate was increased to a little more than 3,000 pounds per acre in four feet depth, the plants were severely affected, their average height being only fourteen inches.

Washingtonia Palm.—A number of these palms are growing along the border of the station tract and county road, in soils containing about 15,000 pounds of alkali salts per acre. The palms look well, though differing in height, and none of them seem to have been affected by alkali.

Date Palm.—A large date palm is growing in a sandy alkali soil at the Tulare substation and is not at all affected by the two hundredths of one per cent of carbonate of soda present. It will clearly tolerate a larger amount. Only a trace of common salt was found in the soil.

Camphor Tree.—The tree is in splendid condition, having a height of fifteen feet and spreading strongly and with good foliage. The alkali is too small in amount to affect it.

Oriental Sycamore.—The carbonate of soda around the roots of this large tree is comparatively small (3,200 pounds), but common salt is present to the extent of more than one tenth of one per cent, which gives the enormous amount of 20,000 pounds per acre in four feet depth. It is clear, then, that in almost any alkali land reclaimed from carbonate of soda this tree will make good growth.

Eucalyptus amygdalina.—This tree is growing well in even stronger alkali land than the sycamore, its tolerance of common salt being more than 20,000 pounds per acre. The amount of carbonate of soda which it will withstand has not yet been ascertained, as there was but 1,900 pounds present here.

Kölreuteria paniculata.—This small tree was found growing in the alkali sump which had received much of the alkali drainage of the station tract, and where the alkali was supposed to be strongest. The amount of carbonate of soda was found to be greater than elsewhere, nearly 10,000 pounds per acre in four feet; but the common salt was less than found in the soil of the eucalyptus tree.

GENERAL SUMMARY OF RESULTS THUS FAR OBTAINED.

The following tables present in brief form for comparisons the nearest approach to maximum tolerance of each of the salts of alkali thus far obtained for fruits and other cultures; giving, of course, the amounts in which each culture was growing and in good condition entirely unaffected by alkali. The cultures are arranged in the order of highest tolerance.

These results are of course only tentative, for in a great majority of cases future examinations will probably greatly raise the figures given in the tables.

Aided by the coöperation of the farmers throughout the State where alkali lands exist, this work will be continued, and we hope to greatly increase the value of the results obtained.

Highest Amount of Alkali in Which Fruit Trees Were Found Unaffected.

Arranged from highest to lowest. Pounds per acre in four feet depth.

Sulfates (Glauber Salt).		Carbonate (Sal Soda).		Chlorid (Common Salt).		Total Alkali.	
Grapes	40,800	Grapes	7,550	Grapes	9,640	Grapes	45,760
Olives	30,640	Oranges	3,840	Olives	6,640	Olives	40,160
Figs	24,480	Olives	2,880	Oranges	3,360	Almonds	26,560
Almonds	22,720	Pears	1,760	Almonds	2,400	Figs	26,400
Oranges	18,600	Almonds	1,440	Mulberry	2,240	Oranges	21,840
Pears	17,800	Prunes	1,360	Pears	1,360	Pears	20,920
Apples	14,240	Figs	1,120	Apples	1,240	Apples	16,120
Peaches	9,600	Peaches	680	Prunes	1,200	Prunes	11,800
Prunes	9,240	Apples	640	Peaches	1,000	Peaches	11,280
Apricots	8,640	Apricots	480	Apricots	960	Apricots	10,080
Lemons	4,480	Lemons	480	Lemons	800	Lemons	5,760
Mulberry	3,360	Mulberry	160	Figs	800	Mulberry	5,760

Other Trees.

Kölreuteria	51,040	Kölreuteria	9,920	Or. Sycamore	20,320	Kölreuteria	73,600
Eucal. am.	34,720	Or. Sycamore	3,200	Kölreuteria	12,640	Or. Sycamore	42,760
Or. Sycamore	19,240	Date Palms	2,800	Eucal. am.	2,960	Eucal. am.	40,400
Wash. Palms	13,040	Eucal. am.	2,720	Camph. Tree	1,420	Wash. Palms	15,280
Date Palms	5,500	Wash. Palms	1,200	Wash. Palms	1,040	Date Palms	8,320
Camph. Tree	5,280	Camph. Tree	320			Camph. Tree	7,020

Small Cultures.

Saltbush	125,640	Saltbush	18,560	Modiola	40,860	Saltbush	156,720
Alfalfa, old	102,480	Barley	12,170	Saltbush	12,520	Alfalfa, old	110,320
Alfalfa, young	11,120	Bur Clover	11,300	Sorghum	9,680	Alfalfa, young	13,120
Hairy Vetch	63,720	Sorghum	9,840	Celery	9,600	Sorghum	81,360
Sorghum	61,840	Radish	8,720	Alfalfa, old	5,760	Hairy Vetch	69,360
Sugar Beet	52,640	Modiola	4,760	Alfalfa, yo'ng	760	Radish	62,840
Sunflower	52,640	Sugar Beet	4,000	Sunflower	5,440	Sunflower	59,840
Radish	51,880	Gluten Wheat	3,000	Sugar Beet	5,440	Sugar Beet	59,840
Artichoke	38,720	Artichoke	2,760	Barley	5,100	Modiola	52,420
Carrot	24,880	Lupin	2,720	Hairy Vetch	3,160	Artichoke	42,960
Gluten Wheat	20,960	Hairy Vetch	2,480	Lupin	3,040	Carrot	28,480
Wheat	15,120	Alfalfa	2,360	Carrot	2,360	Barley	25,520
Barley	12,020	Grasses	2,300	Radish	2,240	Gluten Wheat	24,320
Goat's Rue	10,880	Kaffir Corn	1,800	Rye	1,720	Wheat	17,280
Rye	9,800	Sweet Corn	1,800	Artichoke	1,480	Bur Clover	17,000
Cañaigre	9,160	Sunflower	1,760	Gluten Wheat	1,480	Celery	13,680
Ray Grass	6,920	Wheat	1,480	Wheat	1,160	Rye	12,480
Modiola	6,800	Carrot	1,240	Grasses	1,000	Goat's Rue	11,800
Bur Clover	5,700	Rye	960	White Melilot	440	Lupin	11,200
Lupin	5,440	Goat's Rue	760	Goat's Rue	160	Cañaigre	9,360
White Melilot	4,920	White Melilot	480	Cañaigre	80	Ray Grass	6,920
Celery	4,080	Cañaigre	120			White Melilot	5,840

Since the above was in type the following additional data regarding special cultures at the ten-acre tract of the Southern California substation have been obtained. The analyses of the soils of the several plots show an almost entire absence of common salt, and the cultures have therefore only to contend with carbonate of soda and the sulfates. The figures show the amount of alkali in three feet of soil per acre. The soil is a close-grained black loam, not sandy as at Tulare.

PLOT 8.

Sulfates, 9,880 lbs.; Carbonate, 2,360 lbs.; total, 12,320 lbs.
Cultures all killed by the alkali.

Safflower
Globe Artichoke
Sunflower
Esparto Grass
Bearded Crowfoot Grass
Celery
Dwarf Essex Rape

PLOT 45.

Sulfates, 3,080 lbs.; Carbonate, 2,120 lbs.; total, 5,200 lbs.
Cultures all killed by alkali.

Fennel
Burdock
Caraway
Calendula
Medicinal Rhubarb
Quinoa
Coriander

PLOT 34.

Sulfates, 1,880 lbs.; Carbonate, 1,560 lbs.; total, 3,440 lbs.
Cultures all killed by alkali.

Saltwort
Russian Millet
Golden Millet
Japanese Wheat Grass
Tall Oat Grass
Perennial Ray Grass
Roman Chamomile
German Chamomile

PLOT 19.

Sulfates, 1,520 lbs.; Carbonate, 1,440 lbs.; total, 2,960 lbs.
Cultures all killed by alkali.

Italian Ray Grass
Side Oats Grama
Herds Grass
Crimson Clover
Elusine Barcinonensis
Crested Koeleria Grass
French Lentil
Dal
Fenugreek
Kidney Vetch
Golden Thorpe Barley
German Millet

PLOT 43.

Sulfates, 1,920 lbs.; Carbonate, 1,800 lbs.; total, 3,720 lbs.
Cultures doing fairly well.

Broccoli
Chard
Fennel
Dwarf Essex Rape
Black Rice Corn
White Kaffir Corn
Red Kaffir Corn
Sweet Corn
Teosinte

African (*A. halimus*) Saltbush did not germinate.

PLOT 63.

Sulfates, 1,080 lbs.; Carbonate, 1,320 lbs.; total, 2,400 lbs.
California Flax grew one foot in height and was heavy with seed.

CONCLUSIONS.

A review of the above tables and of the more detailed results brings with it the following conclusions:

1. While for the crops in general the maximum tolerance for alkali salts has not yet been definitely found, close approximations are reached with a number, such as the apple, peach, orange, and lemon trees, with respect to carbonate of soda and common salt. In one or two instances alone was the sulfate of soda the apparent cause of distress on the part of a tree.

2. Grapes and olives thus far stand at the head among fruits in their tolerance of each of the alkali salts; oranges grew in a larger amount of carbonate than did the olive, but that salt was chiefly held below the two surface feet. On the other hand, the lemon seems to be the most sensitive to the effects of alkali, especially to common salt, and next to it the orange.

3. The amount tolerated depends largely upon the distribution of the several salts in the vertical soil-column, the injury being most severe in the surface foot, where under the influence of the unfortunate practice of surface-irrigation the feeding rootlets are usually found. It is therefore important that in alkali regions such methods of culture and irrigation should be followed as to encourage deep rooting on the part of crops.

4. The amount tolerated varies with the variety of the same plant, as shown in the grape.

5. The amount of alkali tolerated by the various cultures varies with the nature of the soil. It is lowest in heavy clay soils and fine-grained soils, in which the downward movement of plant roots is restricted; and highest in loam and sandy soils, in which the roots have freedom of penetration.

6. Some plants, such as the saltbush and alfalfa, are quite susceptible to alkali salts when young, but when the roots penetrate deeply, and the ground is heavily covered with the foliage of the plant, they are immune to a very large extent.

7. Lands heavily charged with alkali may often be made productive for certain crops by the application of irrigation water in sufficient amount to leach the salts down to a depth of several (five or six) feet, and by preventing their subsequent rise by proper mulching, or cultivation until the foliage of the plant itself will prevent evaporation of the soil moisture from the surface of the ground. Alfalfa culture has thus been made highly profitable in lands once so strongly charged with alkali as to kill all vegetation.

8. The reclamation of lands charged with carbonate of soda by

neutralization with gypsum often renders possible the profitable planting of such crops as withstand large amounts of common salt or of glauber salt.

9. The effects of carbonate of soda are seen in the yellowing of the leaves of the tree caused by its corrosive action on the root-crown, whereby the proper flow of sap and food supply to the leaves is prevented. The effect of common salt is seen in the falling of the leaves from the newer branches, and in the blackening and curling of the leaves of pears, as shown in the photograph on the title-page of this bulletin.

10. Sulfate of soda (glauber salt) is hurtful only when present in very large amounts, most cultures doing well in more than 10,000 pounds per acre in four feet depth; saltbush, hairy vetch, alfalfa, and sorghum grew well in more than 61,000 pounds.

11. Barley is better adapted to alkali land than is wheat, for it will withstand the effects of twice the amount of carbonate of soda and common salt. Of course, the carbonate may be neutralized with gypsum, and in the absence of much common salt will permit of the growth of excellent crops of wheat; but where the amount of common salt exceeds 5,000 pounds barley should be given the preference over wheat.

GLOSSARY OF COMMON NAMES USED

African Salt-bush—Atriplex Halimus
Argentine Salt-bush—Atriplex pamparum
Australian Salt-bush—Atriplex semi-baccata
Awnless Brome-grass—Bromus inermis
Bearded Crowfoot-grass—Chloris barbata
Bearded Darnel—Lolium temulentum
Blue-grass—Poa pratensis
Bur Clover—Medicago denticulata
Cañaigre—Rumex hymenosepalus
Chard—Beta Cicla
Dal—Cajanus Indicus
Egyptian Millet—Eleusine coracana
Esparto-grass—{ Stipa tenacissima / Lygeum sparteum }
German Millet—Chætochloa Italica Germanica
Goat's Rue—Galega officinalis
Golden Millet—Chætochloa Italica
Hairy Vetch—Vicia villosa
Hard Fescue—Festuca duriuscula
Italian Ray-grass—Lolium Italicum
Japanese Wheat-grass—Brachypodium Japonicum
Kaffir-corn—Sorghum vulgare var.
Lupin, European blue—Lupinus angustifolius
Many-flowered Millet-grass—Oryzopsis miliacea
Many-flowered Paspalum—Paspalum dilatatum
Meadow Fescue—Festuca pratensis
Meadow Soft-grass—Holcus lanatus
Modiola—Modiola decumbens
Orchard-grass—Dactylis glomerata
Oriental Sycamore—Platanus orientalis
Quinoa—Chenopodium Quinoa
Ray-grass—Lolium perenne and L. Italicum
Rough-stalked Meadow-grass—Poa trivialis
Russian Millet—Panicum miliaceum
Safflower—Carthamus tinctorius
Salt-bush—Atriplex semi-baccata
Saltwort—Salsola Soda (young?)
Schrader's Brome-grass—Bromus unioloides
Sheep Fescue—Festuca ovina
Sorghum—Sorghum vulgare
Tall Fescue—Festuca elatior
Tall Oat-grass—Arrhenatherum elatius
Teosinte—Euchlæna Mexicana
Washingtonia Palm—Washingtonia filifera
White Melilot—Melilotus alba

By an oversight the Spelt and Eleusine coracana were included in the list of vegetables instead of in their proper place.

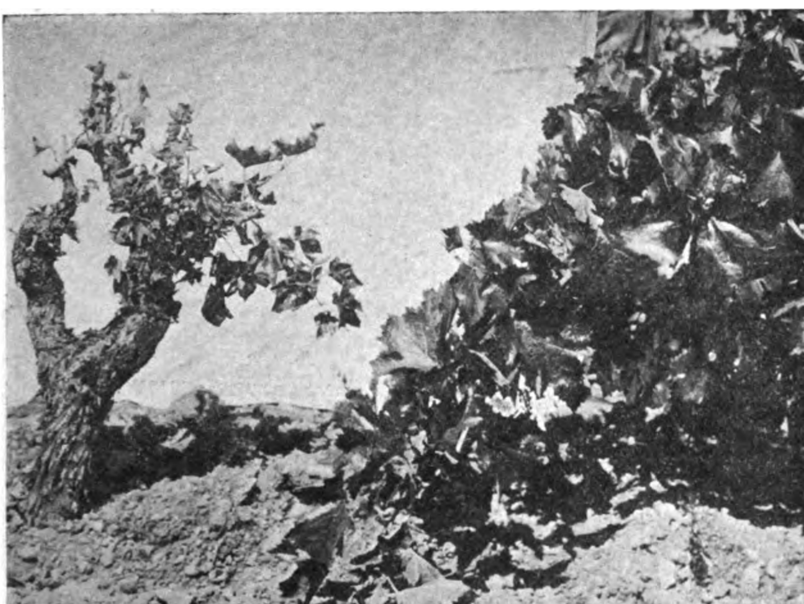
UNIVERSITY OF CALIFORNIA—COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

E. W. HILGARD, Director.

REPORT ON CONDITION OF VINEYARDS IN PORTIONS OF SANTA CLARA VALLEY.

BY FREDERIC T. BIOLETTI AND E. H. TWIGHT.



DECAYED TRUNK. (See page 4.) SOUND TRUNK.

BULLETIN No. 134.

(Berkeley, Sept. 23, 1901.)

SACRAMENTO:

A. J. JOHNSTON, : : : : : : : SUPERINTENDENT STATE PRINTING.

1901.

UNIVERSITY OF CALIFORNIA,
COLLEGE OF AGRICULTURE,
BERKELEY, CALIFORNIA.

AGRICULTURAL EXPERIMENT STATION.
E. W. HILGARD, DIRECTOR.

AUGUST 26, 1901.

PROFESSOR E. W. HILGARD,
Director of Agricultural Experiment Station.

DEAR SIR: In accordance with your directions we have examined the vineyards of Santa Clara with the object of determining the cause of the failure and death of a large number of vines in parts of that county during the last three years. It is not possible at present to give a completely satisfactory explanation for such serious and widespread damage as has occurred, but our observations seem to prove conclusively two propositions: First, that the dying vines exhibit symptoms differing materially from those shown by the vines in Southern California which were destroyed by the Anaheim disease; and, second, that whether or not there be some "unknown influence" at work, as suggested by Mr. Newton B. Pierce, the real, determining factor is the deficiency of rainfall during the years 1897–1900.

Area and General Character.—The dying of vines without perceptible adequate cause during the last three years has by no means been confined to the west side of the Santa Clara Valley. Similar cases have been reported and investigated over a wide area extending from the northern part of Sonoma County, to the western and southern parts of the Santa Clara Valley, and including nearly all the older vineyard districts within these limits. The only peculiarity of the cases on the west side of the Santa Clara Valley is their number, extending in many cases to every vine in a vineyard. The distribution of the injured and dead vines is not in any of the cases examined such as to suggest an infectious parasitic cause. In some instances single vines failed and died sporadically where the main bulk of the vineyard was in fair condition, and a dead vine was usually surrounded by vines which were apparently healthy.

Nature of Injury.—In most of these sporadic cases examined the dying vine was found to have been severely injured in some way, usually by cutting off large branches at the pruning and thus causing large wounds. Vines of this kind when split open were found to be more or less decayed in the middle, and many were quite hollow. In a report made to you last year on the same subject this decay of the interior of the trunk was suggested as the cause of death in some cases. This year, however, though in some vineyards the hollow vines have continued to fail and die, in others they have recovered. This indicates that though the wood decay may have contributed to the effect, it is not the only, nor indeed the chief cause.

The accompanying photograph (plate 1) illustrates the injury done by the cutting off of a large branch.

Note in the subjoined figure the large wound which could not heal over, and which allowed a large amount of wood to dry out. Note also

PLATE 1. VINE INJURED BY HEAVY PRUNING WITHOUT PROTECTION TO WOUND.

the hole made by a boring insect, which allowed the entrance of moisture and of white ants, and thus favored the growth of wood-rot fungi. The stem of this vine was found, on being split, to be quite hollow nearly down to the surface of the ground. For the general appearance of vines of this kind see the frontispiece, which is taken from a photograph of one of the vines as it appeared in 1900. Note the contrast with the perfectly healthy appearance of the neighboring vine.

Nature of Soil.—Nearly, if not quite, all the cases occurred in gravelly soil, and the more gravelly the soil the more numerous and serious the cases. Soil-borings in the most badly affected vineyards showed a layer of many feet of coarse gravel, commencing at two or three feet from the surface. In attempting to irrigate in these places the growers had much difficulty in causing the water to flow to all parts of the vineyard. A large stream of water would take many hours in passing a few yards, on account of the extremely leachy nature of the soil, which allowed the water to escape downward.

Age of Vines.—It is to be noted that none of the dying vines are young. All the vineyards examined which were less than eight years old showed no indications of failing or dying. All cases of young vines

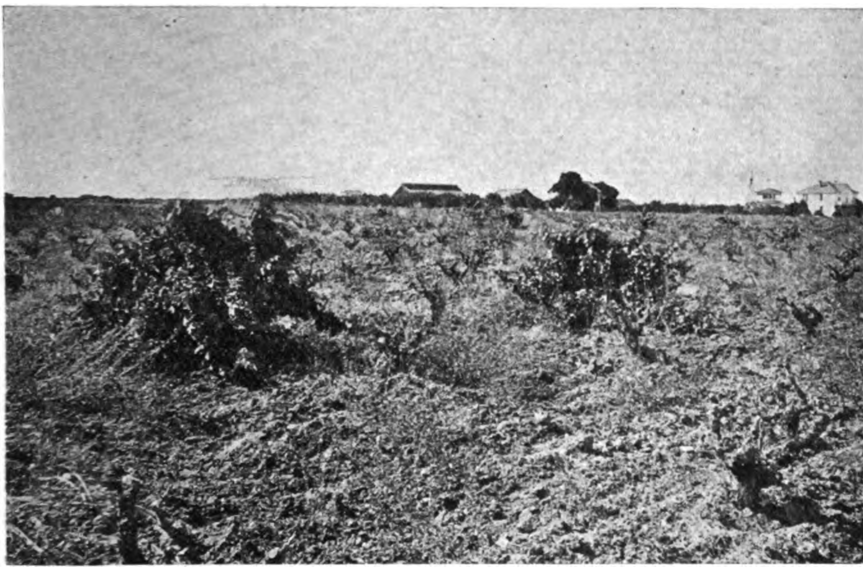


PLATE 2. Two Healthy Trousseau Vines in a Vineyard of Dead Mataro Vines.

failing which were examined were plainly due to lack of cultivation, phylloxera, sunburn, or other well-known and adequate causes.

Another fact worth mentioning in this connection is that old vines which were grafted just before the three dry years, are now nearly or quite healthy. In one vineyard a block of old Mataro grafted with Verdal about 1896 shows strong growth and no signs of failing, while a contiguous block of the same variety and age, but ungrafted, is practically dead.

Behavior of Different Varieties.—A great deal of difference was everywhere noted in the behavior of different varieties of vines. The most seriously affected were Mataro, Zinfandel, Rose of Peru, Mission, Emperor, and Burger. Varieties less affected were Grenache, Muscat, and Verdal. These three varieties, in many cases where they looked very bad last year and even this spring, appear to be recovering. Other varieties show little or no damage. The chief of these noticed were Trousseau, Cabernet-Sauvignon, Pinot (?), Verdot, Robin noir, and Herbemont. This list indicates that the heaviest bearers are the most seriously affected and that all the immune varieties are light bearers. This difference in varieties was so marked that several Trousseau vines growing in a Mataro block were apparently perfectly healthy and vigorous, while the Mataro were all dead. This is shown in the photograph (plate 2). The recovery of less susceptible varieties, such as Grenache, was in several cases very remarkable. Two adjacent blocks, one of Grenache and the other of Mataro, showed a remarkable contrast

PLATE 3. ADJACENT BLOCKS OF MATARO (DEAD) AND GRENACHE (RECOVERING).

when examined in August of this year. Both blocks had made very short growth in 1900, but this year *all* the Mataro were dead, while *none*, so far as could be seen, of the Grenache had died, and though the block had looked sickly in the spring, when examined in August it showed a fine growth of luxuriant foliage (see plate 3).

To recapitulate; the main facts ascertained are:

1. All the dying vines are old.
2. All the serious cases are in gravelly soil.
3. The varieties most injured are all heavy bearers.
4. Vines grafted before the drought are healthy.
5. Vines showing serious mechanical injuries succumb first.
6. Vines which have not become too weak appear now to be recovering.

Causes.—These facts seem to indicate that we can ascribe the failure of the vines to a general cause acting over the whole district; a cause, however, which was only effective where supplemented by one or more contributory conditions. These conditions are:

1. Excessively gravelly soil.
2. Susceptibility of the variety of vine, due probably to heavy bearing and perhaps to some peculiarity of wood and foliage, or roots.
3. Large wounds made in pruning.
4. Age of the vine.
5. Severe cutting back of the young growth by spring frosts.

The *general* cause seems to be the *combined effect of the heavy crops of 1896 and 1897 and the four years of drought which followed.*

Rainfall and Crops.—The following statistical table, made up from data furnished by the Weather Bureau and by two of the largest vine-growers in the most seriously affected districts, fortifies the above position:

Relation of Precipitation and Irrigation to Crop, in Vineyards in Santa Clara Valley.

	Precipitation at Santa Clara.	Crop on Vineyards at West Side.		Departure from Normal Rainfall.
		A (300 acres).	B (170 acres).	
	Inches.	Tons.	Tons.	Inches.
1896	19.51	1,413	....	+3.24
1897	11.82	1,883	*d* 800	—4.45
1898	8.13	500	*d* 215	—8.14
1899	15.56	*a* 449	*d* 93	— .71
1900	13.15	*b* 315	*c* 94	—3.12

[a] Irrigated 35 acres.

[b] Irrigated 300 acres.

[c] Irrigated 70 acres in February. From 50 acres of the irrigated land were obtained 49 tons of grapes, and from the remainder of the vineyard only 45 tons. This indicates about 1 ton per acre on the irrigated and about ¼ ton per acre on the unirrigated portion.

[d] Estimated from the wine produced.

If the figures given for these two vineyards are typical, which there is every reason to suppose, they may help us to find a sufficient cause for the death of the vines without taking refuge behind the mysterious and highly unsatisfactory Anaheim disease. In 1896 the vines bore a large crop, but were supplied with sufficient water by a rainfall of three inches above the normal. They therefore entered the season of 1897 healthy, but probably not with an excess of reserve food-material laid up in the stems and roots; for the weakening effect which a heavy crop often has upon a plant is due to the fact that the nutriment which it absorbs and assimilates during the summer and autumn is nearly all utilized in the production of fruit, and little is stored for use in the following spring. The spring growth of a plant is all due to this reserve food, and is the weaker the less of this reserve it has to draw upon. Usually a year of heavy bearing is followed by a year of light bearing, during which the plant is able to recuperate by utilizing the food assimilated during that year for building up its vegetative organs and for replenishing its depleted reserve. During the season following the heavy crop of 1896, however, the weather conditions were evidently such as to force the vines to expend all their resources in the production of the phenomenally large crop of 1897. How exceptionally large this crop was upon the vines which are now dying is not quite indicated by the table above, which includes the crop from all varieties and ages of vines. The crop on the old vines of heavy-bearing varieties which are now dead was doubtless much in excess of the indicated average. At the same time that this severe drain was being made upon them there was a shortage of over four inches in the annual rainfall. It is practically certain, therefore, that these vines were obliged to start the year 1898 with empty storehouses, and the rainfall of that year being just half the normal, the vines not only bore very little, but were unable to obtain nutriment sufficient to satisfy their vegetative needs and to nourish their permanent organs—roots, stems, and canes.

The next year, 1899, therefore, they commenced to fail and some of them to die. In 1900 still more died, while in 1901, the present year, the largest mortality of all occurred. It is, perhaps, not quite clear why the mortality should be greatest in the later years when the deficiency of rain was less than in 1898, the year of the greatest drought. It should be remembered, however, that a lack of water may affect a plant in two ways: If it occurs at a time when the plant is in vigorous growth and full leaf the plant is injured or killed by diminution of the amount of water in its cells and tissues, due to the excess of evaporation from the leaves over the absorption by the root hairs. In this case the plant dies of thirst and dies suddenly at the time of the drought. If there is, on the contrary, a chronic deficiency of water in the soil, commencing in the winter before the plant commences to grow, the result is simply a small, weak growth of foliage, insufficient to supply food for the needs of the stem and roots. The roots thus having a restricted food-supply fail to grow with normal vigor and in turn fail to supply the rest of the plant with the soil nutrients which it is their function to collect. We have in this latter case not so much injury from thirst as gradual starvation, which is slower in its action and probably, when several dry seasons follow each other, cumulative, as the reserve food-supply becomes each year more depleted until the plant dies.

Summary.—This, then, seems to us the true explanation of the death of vines in the Santa Clara Valley, stated in a few words: *Slow starvation, due to excessive prolonged drought following two exceptionally heavy crops.* That some vines have died and others have lived is due, as we have shown, to coöperating influences, the principal of which are the character of the soil, the variety of grape, the age of the vines, and the exhausting effect of late spring frosts in certain vineyards.

The objection to the drought theory which has been made, that irrigated vines have suffered as much as unirrigated, does not appear to be valid, as, in all the cases which we could find, the irrigation was applied too late. Very little irrigation was practiced until 1899, and then only upon the worst vineyards where the vines were already injured beyond redemption. The irrigation to have been effective, *should have been given during the winter of 1897–98,* the season of greatest drought, and immediately succeeding the two years of abnormally heavy crops. This would have insured the strong growth of foliage during the following summer needed to repair the drain of the preceding years and to replenish the depleted stores of reserve food-supply in the trunk and branches. That irrigation was of some value, even when practiced late, is indicated by the record of vineyard B in the foregoing table, which shows that the irrigated portion of the vineyard produced four times the crop per acre produced by the unirrigated portion, though the amount of water used was only about three inches, or just enough to make up for the shortage in rainfall of the year.

Young vs. Old Vines.—The immunity of young vines, and of old vines which had been grafted about 1897, is explicable on the theory that they were enabled to withstand the drought because they did not bear in 1897 and were thus saved the drain of that heavy crop. The same reason may account to some extent for the immunity of certain light-bearing varieties. That vines on other soils and in other localities have escaped the destruction that has overtaken the West-side vineyards is due doubtless to the fact that the three destructive factors of drought, heavy bearing, and leachy soil have not elsewhere been so great nor simultaneous.

Not Anaheim Disease.—The reasons which have led us to reject as unproven the theory which ascribes the death of the vines to the Anaheim disease are based upon the divergence of the symptoms from those which distinguish that disease as characterized in Bulletin 2 of the Division of Vegetable Pathology of the U. S. Department of Agriculture, entitled "The California Vine Disease," by Newton B. Pierce. This pamphlet must be considered as the highest authority on this disease, as it is almost the only, or at least the most complete and voluminous, publication on the subject.

Characteristics of Anaheim Disease.	*Page	*Characteristics Shown by Dying Vines in Santa Clara Valley.*
Mission more susceptible than Mataro or Zinfandel.	141	Mataro and Zinfandel have died more generally than the Mission.
Vines in shade of trees less rapidly affected.	108	Vines near trees have suffered as much or more than others.
Grafting the vines does not save them.	138	All the recently grafted vineyards are healthy.
Cuttings from affected vines which show the disease die as soon as the parent vines.	152	There are many instances in which cuttings taken during the last two, three, and four years from Mataro and Mission vines which are now dead have been planted, or grafted on phylloxera-resistant stock, and have now resulted in vigorous, healthy vines.
Rotting of the roots is a constant symptom.	52	Roots of most of the injured vines are sound.

*The numbers refer to pages in the above-mentioned bulletin.

To these contrasts should be added the apparent recovery of Grenache vines, which were badly affected last year and this spring, but which in August were making a vigorous healthy growth. Though Mr. Pierce may not make the statement definitely, the impression left, on reading his publications on the Anaheim disease, is that it is cumulative and progressive and that the attacked vines never recover.

These contrasts prove either that the Anaheim disease is not the cause of the death of the Santa Clara vines, or that the characterization of the disease as given in the publication above referred to must be profoundly modified to include the symptoms exhibited by these vines. There is, however, no reason at present to suggest the Anaheim disease if, as seems at least very probable, the causes here outlined are sufficient to account for the observed effects.

Practical Lessons.—This serious disaster contains two important practical lessons to horticulturists, and especially to vineyardists: First, the necessity of having on hand the means for supplementing a deficient rainfall, even in what are usually considered the non-irrigating districts; and second, the importance of choosing varieties adapted to special locations, soils, and climates. This question of adaptation is particularly important to grape-growers who are planting phylloxera-resistant stock, as all the good and thoroughly resistant vines are comparatively limited in their range of adaptability. Wherever new vines are planted in the devastated area it would be extremely unwise to plant any variety which has not well-proved drought-resisting qualities. The resistant vines which have shown the best results so far on the west side of the Santa Clara Valley are Rupestris St. George, Rupestris Martin, and Champini. The last has thriven almost or quite as well as the two

Rupestris varieties, but unless it shows marked superiority in some other way the others are to be preferred on account of their superior phylloxera-resistant qualities and the greater ease with which they root. The suggestion that Rupestris St. George is resistant to the Anaheim disease is certainly premature when based upon its behavior in the Santa Clara Valley, in view of the fact that the presence of that disease in the valley is more than doubtful, for even Mr. Pierce, the acknowledged authority on this disease, after making an examination of the afflicted vineyards, says in the "California Fruit-Grower" of July 27, 1901, that he "will not express an opinion at this time as to the presence or absence of the California (Anaheim) vine disease in this district."

FREDERIC T. BIOLETTI.
E. H. TWIGHT.

UNIVERSITY OF CALIFORNIA—COLLEGE OF AGRICULTURE.

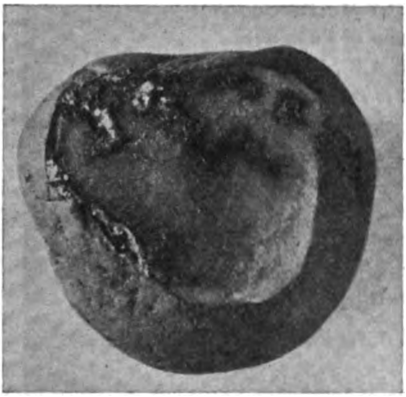
AGRICULTURAL EXPERIMENT STATION.

E. W. HILGARD, Director.

THE POTATO-WORM IN CALIFORNIA.

(*Gelechia operculella*, Zeller.)

BY WARREN T. CLARKE.



INFESTED TUBER.

BULLETIN No. 135.

(Berkeley, October, 1901.)

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1901.

EXPERIMENT STATION STAFF.

E. W. HILGARD, Ph.D., LL.D., *Director and Chemist.*
E. J. WICKSON, M.A., *Horticulturist and Superintendent of Agricultural Grounds.*
R. H. LOUGHRIDGE, Ph.D., *Agricultural Geologist and Chemist.*
C. W. WOODWORTH, M.S., *Entomologist.*
W. A. SETCHELL, Ph.D., *Botanist.*
M. E. JAFFA, M.S., *First Assistant Chemist, Agricultural Laboratory.*
GEORGE E. COLBY, M.S., *Second Assistant Chemist, Agricultural Laboratory.*
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WM. SHUTT, *Foreman,* } Forestry Station, Santa Monica.

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THE POTATO-WORM IN CALIFORNIA.

(*Gelechia operculella*, Zeller.)

BY WARREN T. CLARKE.

NOTE.—The present paper has been prepared in accordance with the policy of permitting properly qualified students of the Agricultural Department to take part in the actual work of the Experiment Station. The insect treated is probably the most injurious species attacking truck crops in the State, but has hitherto received but little attention by entomologists. The study here reported constitutes a very material advance in our knowledge of the life history and habits of the insect and of the problem of its control.

C. W. WOODWORTH, Entomologist.

The most serious potato pest in California is the potato-worm (*Gelechia operculella*, Zell.), a widely distributed insect also known in the Southern States as the Tobacco Leaf Miner or Split-worm.

The damage to the potato crop in California, as estimated by the writer on the basis of opinions obtained from a large number of growers and dealers, aggregates in some years fully twenty-five per cent.

In one section where some of the finest of potatoes are grown, the Salinas Valley, the dealers estimate that at times the loss has gone as high as 40,000 sacks in a single year, and indeed the potatoes from any section of the State have to be watched carefully by the dealers to avoid wormy lots. This need of care is because of the fact that a very few wormy potatoes may infect in a few weeks a whole storeroom full of what were originally clear tubers. As the potato is a food product that is expected to retain its value for many months, this possibility of infestation becomes a most serious question. Certain rots, particularly that produced by a species of Penicillium*, follow the work of the worm, starting in the burrow filled with excrement and ultimately involving the whole tuber.

Potatoes for the Philippine and Hawaiian trade require very careful culling before shipping, because the warm, moist conditions on the voyage into the tropics favor both the insect and the fungus, a single infested potato often spoiling a whole crate.

The injury to the plant in the field, though not as large in the aggregate as that to the potatoes in storage, occasionally results in the total loss of the crop.

*Specimens examined by Mr. O. Butler, of this laboratory, show the presence of a red yeast, a species of Mucor, and of Penicillium, this latter distinctly predominating.

The cause of this loss is not generally recognized by the grower, who commonly designates it as a "mould," "rust," or "fungus." While it is difficult to deal with in the field, yet it can be controlled even there. This failure to recognize the cause has been an important factor in the spread of the trouble.

The injury produced by the worm is extremely evident to the housekeeper and is well known to all dealers in potatoes; but very generally they do not understand the nature of the insect producing the trouble.

Among the commonest misconceptions may be mentioned the idea that it is a form of rot not associated with any insect. Usually, however, the work of the worm is recognized as such, but its connection with any other stage of existence is unknown or misunderstood. The importance of knowledge on this subject rests on the fact that the carelessness of a grower or dealer stands as a constant menace to all the potatoes in the neighborhood.

Though the potato-worm is so injurious in California, and occurs in the East and in many parts of the old world, it appears to be quite unknown in any of the adjacent States, or at least does not appear in sufficient number to cause any marked damage. The Station entomologists of Arizona, Nevada, and Oregon each have written us that the insect has not come to their personal notice.

The insect has long been known to be greatly injurious to solanaceous plants, and has been described by various authors under various names. In all cases where the food habit has been noted, however, it has been found to be working on some one of the Solanaceæ, and in no case on plants of any other family. This restriction of an insect to one food-plant is very common, and in the present case at least simplifies the work of control, but also opens the way for its preservation in the wild plants of the favored family. We find the insect in many cases doing great damage to the tobacco plant (see U. S. Dept. of Agric. Farmers' Bulletin No. 120, etc.), and it is as a tobacco pest that it has been most noted in this country. Its work in California, however, is on the potato, and this bulletin is confined to its damage to that plant.

Bibliography.—The insect was first described by Zeller in 1873 in his Beiträge zur Kenntniss der Nordamerikanischen Nachtfalter, 62, under the name *Gelechia operculella.* The type specimens from which this description was made were received from Texas.

In November, 1874, Boisduval redescribed the insect in Jahrbuch Soc. Cent. Hort., under the name *Bryotropha solanella.* He noted that it caused great damage to potatoes in Algeria, and stated that the eggs were laid upon the young plant, and that the larvæ on hatching burrowed into the stem and then down and through the tissue of the stem into the tuber. This passing of the larvæ through the stem into the tuber is probably incorrect, as it was in no way confirmed by the present experiments.

The next reference made to the insect was by Ragonot, in 1875, in the Bulletin Soc. Ento. France, 5 (v), pp. xxxv–xxxvii, in which he redescribed the insect under Boisduval's original name, with remarks upon its injuries.

In March, 1878, V. T. Chambers, of Covington, Ky., in the Canadian Entomologist, Vol. X, pp. 50–54, redescribes the insect under the name *Gelechia solaniella*, and notes it as mining the leaves of *Solanum Carolinense*.

In 1879, Ragonot, in the Bulletin Soc. Ento. France, pp. cxlvi–cxlvii, again described the insect under the name *Gelechia tabacella* as a tobacco pest.

In 1880, Meyrick, in an article in Proc. Linn. Soc., New South Wales, Vol. IV, pp. 112–114, treats the insect as a potato pest under the name *Gelechia solanella*.

In 1883, Matthew Cooke, in his book "Injurious Insects of the Orchard, Vineyard, Field, etc.," pp. 313–315, notes the insect as having been observed by him in California as early as 1881. He states that "the moths appear about the first of July and deposit their eggs in potatoes after the latter are gathered from the ground and placed in heaps or sacks," and recommends close covering the potatoes after digging as a preventive of infestation.

In 1886, Meyrick makes further notes on *Gelechia solanella* in Trans. New Zealand Institute, Vol. XVIII, pp. 166–167.

In 1889, Mr. Henry Tryon, in his Report on Insect and Fungous Pests, pp. 175–181, treating of the insect in Queensland, quotes from a correspondent of his, Mr. G. Searle, the statement: "The uppermost potatoes, those which are nearest the surface, are of course most easily reached, nor is it by any means a difficult matter for the insect to penetrate to the depth of three or four inches when the soil is open, uncompressed, or lumpy"; and again, "The potatoes, whilst lying exposed in rows, were attacked by the insects." These statements are worthy of note, because of their economic bearing, and they were fully confirmed by the present inquiry.

In September, 1892, the Government Entomologist, Mr. A. Sydney Olliff, in the Agricultural Gazette of New South Wales, reports the insect as a tobacco pest in that colony.

In the same year, Riley and Howard, in Insect Life, Vol. IV, Nos. 7 and 8, pp. 239–242, figure and discuss the insect quite fully, referring to its presence in California, and suggesting that it might have been brought by Chinese gardeners from China. Under the head of remedies, "the immediate destruction of the infested potatoes" is urged, as is also the careful packing or storing of the sound potatoes in tight rooms.

Again, in the same year, Riley discusses the insect in the report of the Secretary of Agriculture, pp. 156–157, and sounds a note of warning in these words: "The undue presence of so serious a pest in California calls for energetic measures. All infested potatoes, wherever found, should be immediately destroyed, and receptacles in which they have been stored should be treated with kerosene. Sound potatoes should be stored in tight rooms." This is good advice indeed, but since it has seldom or never been followed the pest has increased.

The only other reference noted is an article by Dr. L. O. Howard, in the Department of Agriculture Year Book for 1898, pp. 137–140, where the insect is treated of as a tobacco pest; a revised reprint of which appears in U. S. Department of Agriculture Farmers' Bulletin No. 120, pp. 19–22.

The above (by no means complete) bibliography of the insect shows that it is widespread and very injurious to solanaceous plants. It has been described from different parts of the world under various names, but probably Zeller's naming, *G. operculella*, holds, on account of priority.

We here give a partial synonymy of the insect, furnished by Lord Walsingham, and copied from the U. S. Department of Agriculture Farmers' Bulletin No. 120, p. 22:

Solanella Bdv.

Gelechia terella (a homonym), Wkr., Cat. Lp. Ins. B. M., XXX, 1024 (1864). *Bryotropha solanella* Bdv., J. B. Soc. Cent. Hort. 1874; Rag., Bull. Soc. Ent. Fr., 1875, XXXV-XXXVII. *Gelechia tabacella* Rag., Bull. Soc. Ent. Fr., 1879, CXLVI-CXLVII. *Gelechia solanella* Meyr., Pr. Lin. Soc. N. S. W., 112 (1879); N. Z. Jr. Sc., II, 590 (1885). *Lita tabacella* Rag., Bull. Soc. Ent. Fr., 1885, CXI–CXII. *Gelechia solanella* Meyr., Tr. N. Z. Inst., XVIII, 166–167 (1886). *Lita solanella* (Olliff), Agr. Gaz. N. S. W., II, 158–9 (1891).

GENERAL DESCRIPTION.

The nearest relative that we have to this insect that is injurious to crops is the peach-worm (*Anarsia lineatella*), whose ravages are well known to and dreaded by the peach-grower. Both this insect and the potato-worm, as well as most of the moths belonging to this family, are of small size, with narrow, well-fringed wings; very delicate and generally of quite subdued coloration.

The potato moth is grayish-brown, with ochreous tints intermixed. Under magnification it appears to be dusted over with white and black specks. The brown and ochre of the anterior wings is in the form of more or less regular longitudinal bands. These bands, varying in relative size in different specimens, cause a certain amount of variation in color to appear. The general color-effect of the posterior wings is similar to but lighter than that of the anterior wings. Both sets of wings are well fringed, the posteriors having longer fringes than the anteriors. The antennæ are rather prominent, and are inserted just anterior to the center of the compound eyes. The palpi are prominent, gray-brown externally and dusty yellow internally. When at rest the wings are folded somewhat roof-shape over the abdomen, and when in this position the length of the insect is about 8 mm. (⅓ in.). With wings expanded the insect measures from tip to tip 16 mm. (⅔ in.). The illustrations of the insect (Fig. 1) give a very fair idea of its general appearance. Other members of the group differ from it in minute characters that would be noted by an entomologist, but are not found in the same situations. They are quite quick flyers, and are easily recognized in storerooms by their rapid flight toward the light when they are disturbed. The female is somewhat larger and more robust than the male.

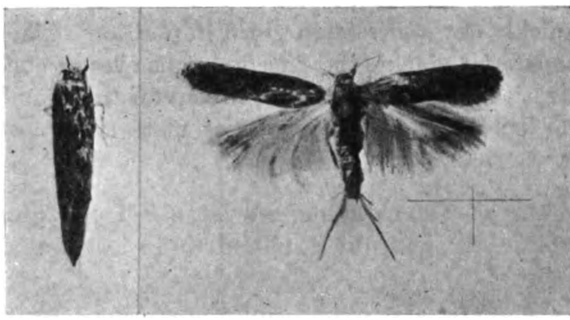


Fig. 1. Adult moth of potato-worm (*Gelechia operculella*, Zell.). Actual size shown by hair line.

The Egg and Oviposition.—The egg is about ¼ mm. in diameter and ½ mm. long. It is of an oval shape, and shows under the magnifying glass the color-play of pearl, its general color being a shining white. Its extreme minuteness and the fact that it is placed in the most inconspicuous positions available render it difficult of detection. We present a microphotograph (see Fig. 2) of a number of the eggs *in situ* about the eye of a potato, which gives a fair idea of their general appearance. The magnification is twenty diameters. The female depositing these eggs was placed in a jar with one thoroughly cleaned potato and was observed in the act of oviposition. She always sought the eye of the potato as the place to lay the egg. Having found a position that seemed to suit her, she settled down flat on the surface at this place, and remained quiet for two or three minutes. Then a drawing of the tip of the abdomen toward the thorax, ventrally, was observed and the

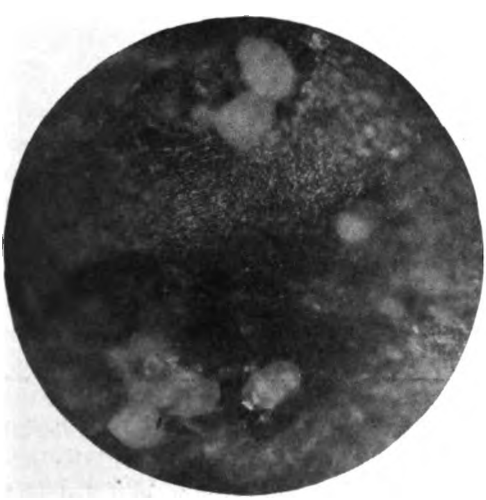


Fig. 2. The Egg. Enlarged twenty diameters.

egg was extruded. The process was repeated for, in one case, three times without any apparent change of position. Generally, however, not more than two eggs were placed contiguously, and in the majority of cases they were placed singly. This particular female laid 22 eggs that were observed. The eggs are viscid externally at first, but they quickly dry and remain glued in position. The position sought by the female for placing the eggs, e. g., the eyes or buds of the potato, presents a satisfactory place of concealment for them, and is also the place where the epidermis of the potato is more easily penetrated by the young larvæ than at any other point.

Larva.—On hatching, the larva is 1 mm. long and of a transparent white color, with the head and thoracic region darker. Its minuteness

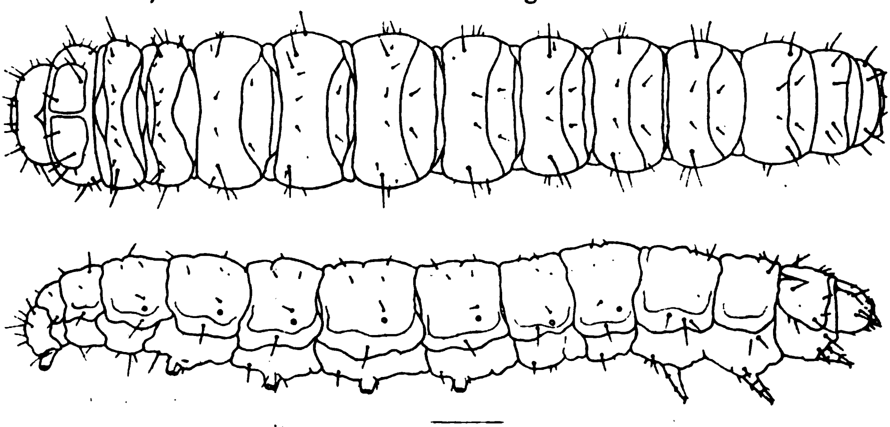


FIG. 3. Larva. Hair line indicates natural size.

renders it difficult of observation, and it is only noticed by the ordinary observer after its second or third molt. At this stage it is quite noticeable, being from 5 to 6 mm. long. The head is characteristically of a dark brown color, with the mouth parts well developed. The first thoracic segment is of a clouded pink ("old rose") color, colored over dorsally with the dark mahogany-colored cervical shield. The second thoracic segment shows the clouded pink color both dorsally and ventrally, and the third thoracic segment is clouded white, as are the seven following abdominal segments. This clouded white color may verge to yellow and to green; this color-change being dependent on whether the larva has been feeding on the heart of the potato or on greener material near the surface. Frequently these abdominal segments will be suffused dorsally with pink. The eighth (terminal) abdominal segment is of a shining yellow color. The various segments are ornamented with sparsely scattered hairs or spines.

The position and appearance of the thoracic as well as of the abdominal legs are shown in Fig. 3.

The Chrysalis and Pupation.—The chrysalis is 6 mm. long, and is at first a light yellow, turning very soon to a rich mahogany and finally to a dark mahogany color. The abdominal segments are conspicuous, and to a late stage in the chrysalis's life are quite free in movement. The wing-folds are free from the abdomen distally; the ventrally-placed antennæ are quite well defined; the eyes prominent. Fig. 4 is a good representation of the chrysalis.

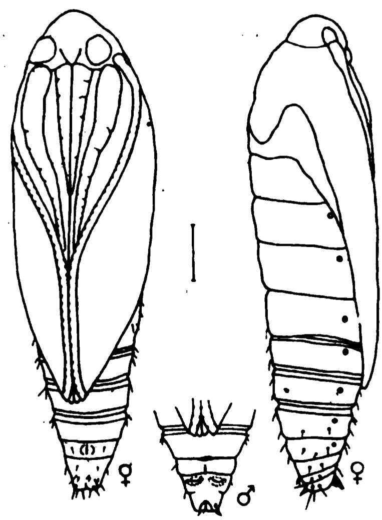
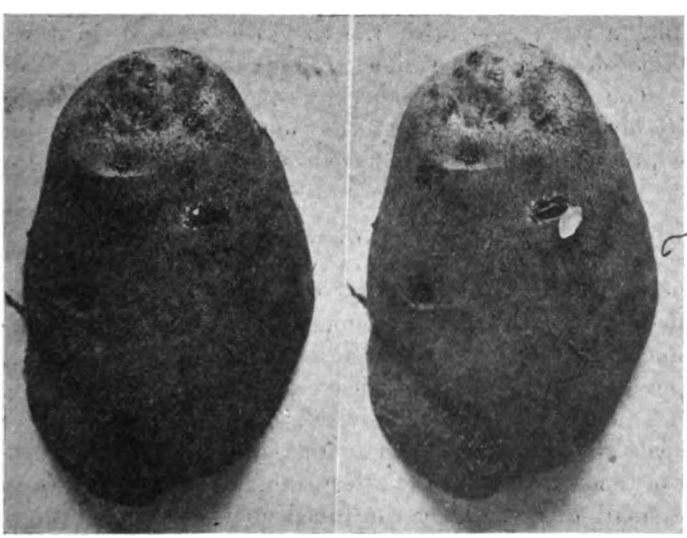


FIG. 4. Chrysalis.

The pupation of the insect is interesting, and can be observed satisfactorily. The larva at about six weeks age comes to the surface and either pupates in the mouth of its burrow after it has broken through the epidermis, or seeks some depression on the potato, or may find its way into some crack or cranny of the receptacle in which the potatoes are stored. It has been frequently observed, during this investigation, to find its way into the fold of the sack in which the potatoes are kept. Generally speaking, then, the



Pupa case closed. FIG. 5. Pupa case open.

worm finds a more or less secluded place and there pupates. The satisfactory spot having been chosen, it proceeds to spin its silken cocoon therein. A carpet piece of silk is well fastened to the surface, the cover piece being woven at the same time, the two together forming a sort of pocket, smooth and white on the inner side, but on the outer side covered with bits of frass, trash, etc., and assuming the appearance of a piece of dirt and nothing more. When this covering is arranged satisfactorily externally the worm gets beneath it and sews together the opening remaining at the end of the pocket, and transforms to the chrysalis in safety within it.

Fig. 5 shows a pupa case placed within a very slight depression to conceal it, and also the same pupa case with the cover torn loose and turned back and the chrysalis in sight; while Fig. 6 shows, at the end

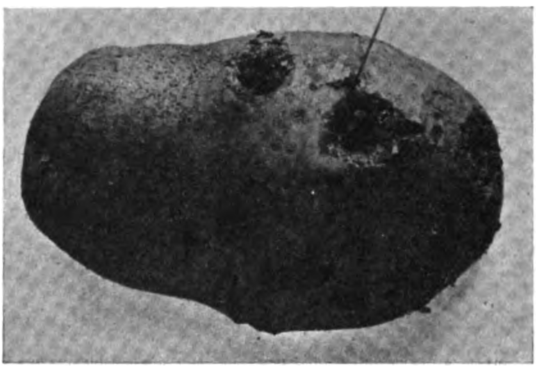


FIG. 6. Pupa case in wound caused by Stenopelmatus.

of the pin, a pupa case, with the chrysalis exposed, in a wound in the potato caused by the yellow ground cricket (*Stenopelmatus* Sp., fig. 10). The pupa cases are generally so cunningly concealed beneath their bits of dirt and trash that they may easily pass unnoticed, but they are quite pervious to air and are easily destroyed. (See Remedies, p. 27.)

LIFE HISTORY.

A series of observations covering the life of the insect for nearly eleven months was taken. Two lots of moths were studied concurrently, and the results seemed to agree in the main points. A lot of young potato plants, stalks and leaves, with very small potatoes, was obtained and kept in a gauze-covered case. The stalks were much infested with the larvæ, and as these stalks wilted the larvæ worked their way out of them and across the intervening space of 10 cm. (4 ins.) and into the small tubers. They continued to work here until ready to pupate, and then came to the surface and placed their chrysalides in depressions on the potato. The age of the larvæ in the stalks was not known, but the first to pupate tunneled out of the potato on the fifth day after entering, and in eight days all had pupated. On the thirteenth day after pupation the first moth emerged, and on the sixteenth day all had emerged. This gives the period of pupation in this generation as from thirteen to sixteen days. The adult moths can carry on the life functions without eating, and hence breeding in storage is quite easy.

The moths mated soon after emerging, and oviposition was noted on the second day after emergence. The first larvæ noted were recognized eight days after oviposition, and new larvæ appeared on the two following days. These young larvæ were carefully observed, and forty-two days later they began to come out of the potato and to pupate, and continued to appear for three days thereafter.

The second lot of moths was carried much further than this lot, and their history is as follows: A lot of infested potatoes was purchased from a dealer, and on September 17, 1900, nine moths were taken from this lot and placed with some uninfested potatoes; on the 18th, the copulation of two pairs was noted; on the 20th, three females were noted ovipositing (see Oviposition, p. 9). On September 28th three larvæ were noted; on the 29th six larvæ, and on the 30th five larvæ. On November 12th two larvæ came to the surface and made cocoons; on the 13th six larvæ went into this condition; on the 14th twelve more, and on the 15th six more. On November 28th three moths emerged, on the 29th seven moths, on the 30th eight moths, on December 1st seven moths, and on December 2d one moth. On December 2d a number of moths from this generation were placed in breeding cages with uninfested potatoes, and on December 3d oviposition was noted. On December 10th larvæ were recognized, and these larvæ began to spin up on January 21, 1901, and by January 23d eighteen cocoons were noted. On February 7th the moths had begun to emerge, and on February 8th fourteen adults were noted. This gave about the same time for this generation to complete its cycle as in the previous case.

The same process of placing the moths with uninfested potatoes was repeated and the same results obtained, save in the case of the larvæ, where the life period was extended to nine weeks (a sort of hibernation?), and adult moths appeared on the 4th day of May, 1901. Again was the process repeated, and a new lot of moths appeared on the 9th of July, when the breeding was abandoned.

We may summarize the life history thus: To complete the cycle ordinarily, 63 to 69 days are needed, save for the winter generation when this time may be extended to 84 or 85 days; this, of course, under the temperature conditions of Berkeley. This time is divided thus: Egg stage, 7 to 10 days; larvæ, 42 to 45 days ordinarily, winter generation 9 weeks; chrysalis, 14 to 16 days; adult life, indefinite but short.

This study of the life of the insect is significant from the fact that the conditions for living and propagating were the same as are found when potatoes are stored, and the result indicates conclusively that the injury is progressive. A very small primary infestation may in a few weeks mean the complete ruin of the infested lot. Also, it is to be noted that the adult moth is ready for the young potato plants as soon as they appear in the spring. Under storage conditions the generations will not be so clearly defined as in the laboratory conditions, and there will be an apparent lapping-over of broods, and adults will be noted at all times. This "lapping-over" of course results in the adult being ready to do damage at almost any time that material is presented for it to work upon. The necessity is obvious, therefore, of destroying the moth in infested storerooms, bins, etc., and not permitting it to escape and spread the infection. This aspect of the case will be treated of more fully under the heading of "Remedies."

CHARACTER OF INJURY.

The injury done by the insect naturally falls under two heads: the injury to the growing plant and the injury to the tubers. The character of the injury in the first case, that of to the plant, has been touched on on page 5, and is perhaps not so often noted as is the injury to the tubers. When the moth oviposits on the plant she seeks some desirable position, such as the base of a leaf, in which to place the egg, and the young larva on hatching immediately burrows beneath the epidermis of the plant and eats its way along downward, always just beneath the epidermis. This burrow can be quite easily traced when the larva begins to attain some size, and by careful search can be detected even when the larva is quite young. The worm fills the burrow behind itself with excrement, and this ejected material turns quite dark in color. Following in the wake of this primary injury is the inevitable mould and fungous growth, and the stalk soon succumbs to the combined injuries, the actual material taken as food by the worm and the consequent decay.

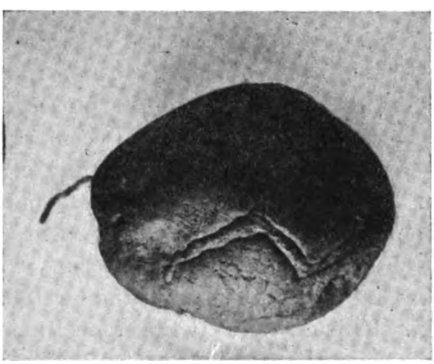


FIG. 7. Sub-epidermal burrow.

The injury to the tuber is very similar to that to the plant. The worm enters the potato and burrows its way through the tissue of the tuber. This entry is in the bud, and the point of entry is generally marked by a little pile of excrement. The worm having succeeded in entering, tunnels along beneath the epidermis or right through the substance of the potato. It does not seem to be at all particular which method it follows, and indeed may show both kinds of work. When the burrow is sub-epidermal it may be easily traced by the shrinkage of the potato on either side of it, as is shown in Fig. 7. When the burrow is in the substance of the potato it is very evident and can be easily traced by the discolored excrement. The frontispiece illustrates both kinds of work. The potato has been cut in such a way as to show both a sub-epidermal burrow and also certain burrows into the body of the potato. These burrows are filled with excrement, and render the potato wholly unfit for human food. The burrows, with their excremental filling, soon become the starting points for rots and fungous diseases, as previously noted (p. 5), and the injury is complete.

MODES OF INFECTION.

There are various ways in which the potatoes may become infected, and these ways may be described in this order:

By infection of the stem: The adult female moth, being on the wing when the young potato plant appears above the ground, oviposits on the plant itself at a point near the junction of a leaf with the stem. The larva hatches and immediately begins work by "mining" a burrow beneath the epidermis. The general trend of this burrow is downward, though a spiral course may be pursued. If the attack has been made on a very young plant the larva may come to maturity and work its way out of the stem and pupate in the ground beside the plant or in some depression in the stalk itself. In this case the tuber is not injured, but the plant suffers both because the nutriment has been taken from it and also because of bacterial and fungous diseases bred in the excrement with which the burrow is filled. Cases have been reported to us where hundreds of acres of potatoes have been wholly lost through an attack of this kind. If the oviposition takes place in an older plant, the larva burrows down the stalk as before, but the hardening of the plant causes it to leave and enter a tuber and continue operations there. This entry is generally made near a bud or eye, and the larva actually passes out of the stem and through the surrounding earth to the tuber, and not down the stem and into the tuber, as is generally stated. On infested plants observed in the laboratory the larva left the stalk and crossed over the space of one decimeter (4 inches) of earth to potatoes placed at this distance from them. When the larva had found the potato it would wander about the surface for some time, twenty-four hours in some instances, but seemed to have no difficulty in finally piercing the skin and entering.

By direct infection of the tuber in the hill: In the experimental plot it was noted that in many cases there were tubers that were not completely covered in the "hilling" process. The exposed portions of these tubers, being open to the light, turned green, and the moth oviposited in these green places. The fact that the fully covered tubers in the same hill were entirely free from the larvæ, and the further fact that in some cases remnants of the egg were found in these green places on the potatoes, shows the direct infection in the hill.

Direct infection after digging: The moth will oviposit in the potatoes that are left exposed in the field after digging. Many perfectly clear tubers were so exposed, and in the large majority of cases these tubers were later found infested; in one case five larvæ were taken from one potato.

Indirect infection after digging: If the stems are infested at the time of digging, the larvæ will leave them and find their way to and enter the tubers, if these are available. The common practice in the potato fields of covering the piles of newly dug tubers with the leaves and stems of the plants by way of shade is a sure way to secure infestation if the latter contain larvæ. Even though the leaves and stems may be uninfested the practice of using them as a covering is not to be commended, as when they are used for this purpose they also furnish a place of concealment for the moth in close proximity to the tubers.

Infection in the sack or bin: The moth will oviposit on the stored potatoes. A number of clear tubers were placed in a gauze-covered box, and a lot of the moths placed with them. Infestation always followed this experiment.

EXPERIMENTS IN FIELD OR STOREROOM.

The experiments here detailed were carried on with the surrounding conditions made to conform as nearly as possible to the natural conditions. The field work in all its aspects was a duplicate of the ordinary farm conditions, and the laboratory work might well pass for a series of experiments carried on in storerooms. It is believed that the field results obtained can be obtained in regular farm practice, and that any one storing potatoes can duplicate the results obtained in the laboratory. As a matter of course, great care was exercised, not alone in carrying on the experiments, but so far as possible this was done with a view to the expense account, and no work requiring a heavy outlay was attempted, nor would such be required in commercial practice. Infested potatoes were purchased in the open market and used for laboratory experiments, as well as the product of a patch of sound potatoes planted on the Station grounds. This patch and its product served as a basis for much of the field observation and experiment, and this work at the Station was supplemented by studies made in large fields of infested potatoes and by observation and inquiry in the warehouses and storerooms of many dealers. Whenever cases were reported that appeared to present features of value in this inquiry no pains have been spared in investigating them, and as a result we are able to present a fairly complete account of the insect and its work in California, which knowledge, if applied in handling potatoes, should cause a marked diminution in the loss from the work of the insect.

Field Experiments.—On March 7, 1901, the experimental patch of potatoes was planted on the Station grounds in Berkeley. The soil is a medium heavy loam, and was well plowed. The seed-potatoes used were Oregon Burbanks, and were perfectly clear of infestation. The season was rather cool, and the potatoes did not appear above ground until April 1st. By the end of April the plants were growing well and were quite thrifty. Scarcely any plant-infestation was noted up to this date, though to insure, if possible, such infection a number of moths, bred in confinement, were liberated in the patch on April 5th. Whether these were the moths that were instrumental in infecting the plants is of course open to question; however, on April 25th six affected plants were noted, and on two of these remnants of the eggs were found. The affected stalks were cut off and destroyed in these six cases, and the result was a complete stoppage of the trouble with these plants. The plants seemed to suffer in nowise from this lopping-off process, and when these hills were dug it was found that the yield was up to the average of surrounding hills. It must not be understood that the whole head was removed in these six cases—only the affected stalks were cut off just below where the trouble was manifest. On the night of April 25th, after the affected stalks had been noted, an experiment was tried with a crude lantern trap, and in one hour fourteen of the moths were taken at one candle. The trap was merely a small sheet of bright tin used as a reflector, and a candle set up in a basin of water on which a little kerosene oil was floating. This trap was tried subsequently a number of times, and demonstrated beyond a doubt that the moth can be destroyed in large numbers by the use of light-traps. It is interesting to note in this connection that more potato moths than of all other species combined were taken, and that the majority (60%) of the potato moths taken at this trap were females; and since one female lays many eggs and can infect many plants, the value of this method of destruction is evident. It was not desired to reduce the moths to below the danger limit on this patch, so the light-experiments were at no time carried on for more than an hour. The moths taken at the light certainly came from the surrounding locality, the date of capture as well as their numbers precluding the possibility of their being those originally turned loose in the patch, and it was also too soon for their progeny.

As the worm, on hatching, at once burrows into and feeds upon the tissue of the plant, and as the egg is laid where it is difficult to reach with sprays, no experiments along this line were made.

The next field experiments tried were when the potatoes began to form and the time of hilling arrived. The earth about a number of plants was well pulverized, and this specially pulverized earth used to hill with. The result was a good, compact hill, with the potatoes well covered and difficult for the moth or worm to get to. When the potatoes were dug from these hills no infestation was found in them, though the check hills on either side were infested. These check hills were "hilled" in the ordinary way, and the earth here being quite cloddy certain of the potatoes were somewhat exposed. In every case of such exposure it was found that the potato was infested. In certain of the hills the earth was scraped away so as to expose one or more of the potatoes to the light. The exposed parts of the potatoes turned green, and it was found in every case that these potatoes were infested and that the work of the worm began in this green part. Likewise, taking the whole field when the potatoes were finally dug, it was found that 95 per cent of the ones showing green places were infested, and that the infestation in every case began in these green places. Furthermore, in all cases where potato fields were found infested it was noted that this rule held—that the soil was either lumpy and the potatoes exposed more or less, or was fine and dry, quite sandy for instance, but not compact. In either case the potatoes were easy to reach.

Again, it has been noted in the course of this investigation that right in the midst of affected fields a field will be found in which the tubers are not affected, and invariably the reason of this non-infestation has been found to be the careful hilling of the plants. It has further been noted that a rain coming after hilling, as occasionally happens, has a tendency to compact the earth, and the potatoes which were covered in these compacted hills were unaffected. Indeed, all the experimental work and all the field observations point to the fact that *careful compact hilling reduces the infection to a minimum*, and too much emphasis cannot be put upon this phase of farm practice.

Finding that the potatoes exposed in the hills were almost invariably infested led to a series of experiments on the question of exposure. It was noted that in ordinary farm practice the potatoes are frequently left exposed for varying times when digging was in progress, and a number of potatoes known to be uninfested were left exposed in the field for times varying from two to ten hours in daylight. The following table gives the results of this experiment:

Table Showing Results of Exposure Experiments.

Lot.	Number of Potatoes.	Time of Exposure.	Hours Exposed.	Number Infected.	Percentage of Infestation.
A	40	8 A. M. to 10 A. M.	2	1	2.5
B	40	8 A. M. to 12 M.	4	4	10.0
C	40	8 A. M. to 2 P. M.	6	9	22.5
D	40	8 A. M. to 4 P. M.	8	17	42.5
E	40	8 A. M. to 6 P. M.	10	29	72.5

It will be seen from this table that a very small percentage of those potatoes which were exposed for the shortest time, two hours, were infected, and the increase in infection shown in the second lot, B, where the exposure was two hours longer, is not large. The rise in per cent of infection shown in lots C, D, and E is significant, indicating, as it does, not only the danger of long exposure, but also the rapid rise in infection in the latter part of the day. The results show that *exposure of the tubers should always be avoided*, and that special care should be taken not to expose them in the late afternoon.

Another experiment tried in this matter of exposure was to leave a lot of forty potatoes out in the field from six o'clock in the evening until eight o'clock the next morning. The result was that all of the potatoes were infected, showing the *extreme danger in leaving the potatoes exposed in the field over-night.*

Another series of experiments was based on the fact that it had been found in the laboratory that the worms would leave infested stalks when they began to wither, and enter the tubers. When the potatoes were dug, a number of tubers known to be uninfested were stacked in the field and covered with the infested stalks, and this pile was in turn closely covered with cloth, so that no direct infection by the moth could occur. As a check to this experiment an equal number of uninfested potatoes were stacked in the field, but no stalks were piled upon them. This stack, too, was closely covered with cloth. Of the potatoes covered with the stalks 70 per cent were finally found to be infested with the worm, while of those not covered with stalks none were infected. Now, it is a common practice in the potato fields to cover the newly-dug tubers with the stalks, and if these stalks are infested the tubers are sure to suffer. Furthermore, even were the stalks uninfested the practice of covering the tubers with them is highly undesirable, as a good shelter for the moth is thus formed. Observations in the field show that the moth is particularly abundant in piles of the stalks, and it may be expected that, taking advantage of this shelter if it is present in the field, it will lay its eggs on the tubers below.

A series of experiments was tried on plants with infested stalks, the infection occurring in this case when the plants were quite old. The experiments were suggested by the fact that as the plant begins to ripen and harden the worms leave the stalks and seek the more succulent food found in the tubers in the ground. The plants selected for these experiments were watched quite closely, and one week before time of digging the heads were cut off just beneath the ground. These heads, with the larvæ still in them, were removed and destroyed. When these hills were dug the potatoes were found to be uninfested, though the check hills with worms in the stalks were infested, the worms having left the stalks and entered the tubers. It was also found that the potatoes in these decapitated hills were, if anything, better and larger than those in the check hills in which the heads remained undisturbed.

We have, in this matter of *removing and destroying infested heads*, a very promising means of defense against the moth, and one that is easily used in field practice. The cheapest and at the same time the most satisfactory way of removing the heads has been found to be by the use of a knife. The method of procedure is for a man to walk along a row, and when an infested plant is found by him to cut it off just beneath the surface of the ground. With a little practice the infested plants will be easily recognized from their somewhat wilted appearance. Other men follow the cutters, gathering up and removing the stalks from the field. These stalks should be placed in piles and covered with a few inches of earth, and fermentation and heating soon following, the larvæ are destroyed. The piles of decayed vegetable matter may be spread over the field and plowed-in, thus enriching the soil.

All of the experimental work in the field indicated the necessity of avoiding exposure of the potatoes as completely as possible, and where this non-exposure policy was fully carried out it was found to eliminate entirely this source of infection.

The conclusions arrived at in the work outlined above were confirmed by the results obtained in another plot of potatoes planted on the Station grounds, but for purposes other than the study of the potato-worm. This plot was also seeded with Oregon Burbanks, and the work done upon it was exactly that which prevails in ordinary farm practice. No particular care was taken in hilling, and exposure at digging was not in any way guarded against. The yield of this plot was practically worthless, 75 per cent of the potatoes being wormy, and yet the original danger of infection was no greater than in the case of the experimental plot.

The results obtained from these exposure experiments led us to another series of investigations. It was noted that the moth was almost sure to find the potatoes if they were in the field, and the question arose whether they would winter in potatoes left in the field. To decide this question a number of infested tubers were left out of doors in gauze-covered receptacles, but exposed to all weather conditions occurring through the winter. Many of these potatoes rotted completely before the winter passed, but some of them remained in sound enough condition to carry the insects through the winter, and far enough into the spring for the young potato plants to be sufficiently grown to furnish a feeding-place for the larvæ. This would indicate that if waste potatoes were left in the field after digging, the moth would be carried over the rainy season in them, and this is just what seems to have happened in the following case. In the course of this investigation an isolated field of potatoes three acres in extent was found to be badly infested with worms, so badly, indeed, that the tubers were wholly unsalable. The field is owned and worked by a gentleman who runs a country store in a near-by village, and its history was obtained from him. In 1899, the crop was good and not wormy. In 1900, some worms in the potatoes and some complaint from buyers. In 1901, potatoes so wormy as to be unsalable. Methods of planting, cultivation, etc., the same each year. Soil a sandy loam, well drained. Small and waste potatoes and tops always left on the ground and plowed-in. An investigation of the neighborhood disclosed a small amount of "night shade" (*Solanum nigrum*), but hardly enough to more than account for the original infection. There was always a number of potatoes on the ground when seeding began. The progressive infestation noted in this field, which is an example of many fields, was evidently due to this item of bad farm practice, viz., leaving the waste product on the ground.

As a corollary to the results noted in this case, care should be taken *never to use infested seed potatoes*, as the moth is more than likely to come out from them in force, in time to infect the young plants; and, besides, the best farm practice is to use the largest and most vigorous potatoes as seed. In infested potatoes the worm has taken so much of the substance and thus robbed the young plant of so much of the stored nutriment that it will be correspondingly weak, and will to this extent more quickly succumb to the attack of the worm. It is also generally conceded that in an insect attack the less vigorous the plant the more likelihood that the insect will choose it to work upon.

Storage Experiments.—The experiments carried on with stored potatoes were intended, first, to determine the life history of the insect (see p. 12); second, to discover whether the life of the pest could be continued through several generations or indefinitely without the adult having access to food; and finally, to determine what means could be used most practically to stop the infection in the potatoes if it were found that breeding did take place freely among the stored tubers. To initiate these experiments infested potatoes were obtained and placed in gauze-covered receptacles, and the emergence of the moths noted. When the moths were quite numerous in these receptacles fresh potatoes that were known to be uninfested were introduced. These potatoes were marked so that they could be easily identified at any time, and sooner or later they were always found to be infested, thus proving that the moths could and did breed in storage, and that the damage from them was continuous and progressive. The study of the life of the insect (see p. 12), carried on as it was from the end of one growing season to the end of another, eleven months later, proved that this breeding in storage could extend over several generations—four, as noted in this investigation. This continuance of the moth under storage conditions proved, also, how numerous the progeny of a single pair may become in a few months, for at no time was any disease noted among them, nor was any parasitization observed, and their life work seemed to be carried on practically unhindered.

That the female moth may lay twenty-two eggs has been noted, and considering that half of the eggs laid will produce moths of the same sex, we find the progeny of a single female will, if food is present, number at the end of six months some 15,000 moths ready to oviposit upon any potato plants that may be present.

Of course, there would be natural checks to the moth when its life is carried on out of doors and when having to contend with unfavorable weather-conditions. Two of the breeding-cages used were not interfered with at all from the first of November, 1900, to the last of March, 1901. Ten potatoes were in each of these cages, and when they were finally abandoned the potatoes had sent out sickly sprouts and these sprouts had been killed by the worms working in them. The potatoes themselves were honeycombed with the burrows of the worms, and were so shriveled as to be hardly recognized as potatoes. Some of them had rotted, but by maintaining dry conditions as far as possible most of them had escaped decay. The dead moths in these cages were not counted, but they were numerous enough to fill a half-pint cup, proving that the breeding was carried on in confinement under loose storage conditions.

To decide whether the progressive infestation went on if the tubers were packed as in sacks, two ten-pound lots of potatoes were put up in ordinary jute sacking. One of these lots had no infestation, while in the other lot several infested tubers were placed. These two sacks were put close together in a gauze-covered box, and left for three months. On examination at the end of this time five infested tubers were found in the sack that was originally uninfested, and in the other, the originally slightly infested sack, hardly a good uninfested potato was found. That the infection may spread in sacked potatoes and from one sack of potatoes to another in the same pile cannot be doubted.

Experiments with Carbon Bisulfid.—It having been conclusively shown in this investigation that breeding went on rapidly in the stored potatoes, methods of destroying the pest were sought for—methods that would be effective even when the potatoes were piled "heavy" in the storerooms. We believe that there is no way of reaching the worm when it is once in the potato, except the destruction of the potato itself. A potato that is wormy may be looked upon as hopeless, and should be rendered harmless in the spreading of infection, by being boiled and fed to hogs or destroyed in some other way. But it is impossible in the generality of cases to destroy or even find these infested potatoes before they have spread the infection, and so the question reduces itself to stopping the latter without attempting to find and destroy the individual tubers that are affected. Both the pupæ and the newly-emerged moth are easily killed, and it was considered that in these stages the vulnerable point was to be found.

Numerous experiments were made to test the susceptibility of the chrysalis to the fumes of carbon bisulfid (CS_2), and these proved that we have in this substance the means of controlling the insect, so far as the infestation in stored potatoes is concerned. These experiments were made in the following manner: Potatoes were taken with pupæ on them of all ages, from those which had just spun up to those just ready to emerge. These potatoes were placed in a tight box and a varying amount of carbon bisulfid put in a shallow dish on top of them, and then a close cover put on the box. This "bin" was allowed to stay closed two days, and then the potatoes with their pupæ attached were removed to the gauze-covered cases and closely watched. Every chrysalis was dead, as was shown by no moths emerging, though the observations were kept up for eight weeks.

The amount of carbon bisulfid used in this and the following experiments was not measured, though it was in no case more than one drachm to the cubic foot of space, and the amount used was in all cases more than enough to kill all chrysalids. The amount recommended to be used, under the head of "Remedies," is based on the calculations made for the disinfection of grain in bins.

These experiments were followed by others, in which the life-history study was used as a guide for the time to apply the poison. In each experiment there were used a number of infested tubers in which the worms had not begun to make their cocoons. It was supposed that there might be larvæ of all ages in these potatoes, and also possibly some pupæ on them, so the tubers were treated with the bisulfid as soon as placed in the "bin." Two weeks later the potatoes were again treated with bisulfid, and this was repeated twice more at intervals of two weeks, when it was considered that probably all the worms had spun and all the chrysalids were killed. This proved to be the case, for the infestation in this lot was ended, and though the once infested potatoes finally rotted, this did not occur until ample time had elapsed for the moth to appear, if any of the insects had remained alive. Several experiments were tried in this line with a less number of treatments, and while some were successful where but three applications of bisulfid were made, this reduction of the number of applications was not always a success, for the infestation continued in some cases.

The fact before noted, that under ordinary storage conditions there is more or less lapping-over of generations, must be borne in mind, and if infestation of the tubers is suspected or noted, then a treatment immediately on their being placed in storage is imperative. This first treatment kills all pupæ that may have appeared before this time. The second treatment cares for all the chrysalids that may appear after the first treatment, and does not give time for the moth to emerge from them; the third treatment disposes of the pupæ that may appear after the second treatment; while the fourth treatment finishes all possible late pupæ. This is under the supposition that potatoes unexposed to the moth after digging, are being dealt with. If the potatoes have been exposed after digging there is a possibility that there will be eggs on the potatoes treated, and a fifth application of carbon bisulfid becomes necessary. This fifth treatment should be given at the end of the eighth week of storage. So completely successful was the work with the bisulfid that in none of the experiments where it was used did a single chrysalis escape, and in no case did its persistent use fail to stop infestation.

REMEDIES.

In discussing the experimental work under various headings, remedies have been noted that proved successful in practice, and the various recommendations here made have been tested under working conditions in actual practice. Attention, however, must be drawn to the fact that in any case of infestation there comes a point where remedies, that at one time would have been successful, are useless. So, in handling an insect attack, we must not wait until the insect is out in force and then try to rid our crops of the pest, but the fight must be begun when the invasion is in its incipiency, and beginning thus we may confidently expect our efforts to lead to success. The farmer who carefully watches his potato field, and is ready to begin the battle against the moth when it first appears, has an easier fight than he who waits until the full army of the moth is in array against him; and so it is all along the line until the potatoes are marketed.

By vigilance and watchfulness, as well as by the use of discrimination in suiting the remedy to the conditions, the insect may be controlled, even in the localities worst affected.

Food Plants Should Be Destroyed.—As has been before stated, the insect, according to all observations, confines itself in its larval form to solanaceous plants, and its great injury is done among the cultivated representatives of this family, notably in the potato and tobacco. It has been reported as feeding and breeding among the wild members of the family, and this feature of its career was considered of value in this investigation, because if any of these wild members were to be found near the cultivated plants they would constitute a good breeding-place for the insect and a point for infection to originate. We have in California much of the so-called "night shade," the *Solanum Douglasii*, *S. nigrum*, *S. umbelliferum*, and *S. Xanti*, and where these plants are found the insect is sure to be found also, as collections made among and near them have shown. Furthermore, collections, especially at lights, made hundreds of feet from any solanaceous plants, have shown the moth to be present, thus indicating its ability for flying quite long distances. This, together with the fact that the insects are not confined to the cultivated plants of the family *Solanaceæ*, but attack the wild representatives also, at least suggests that any patch of such plants as the night-shades constitutes a menace to any potato plants in the neighborhood, and that all such patches should be destroyed.

Light-Trapping.—It has been noted (p. 17) that the moth is easily taken in large numbers at lights, and in the use of light-traps we have a most effective method of killing it. The use of the light-trap, too, is a most satisfactory way of finding out whether the moth has begun to work in a potato field, as two or three such lights scattered about the field will surely show specimens, if any are flying. If the moth is found to be present, then the traps might be placed in the field at intervals of 100 feet or so, and kept in action each night until moths fail to be taken at them. It seems most probable that the persistent use of these traps at this time will greatly reduce the possibilities of infestation. There are various forms of these traps on the market, and some of them are quite effective, though probably not more so than the common lantern trap, made by soldering a torch body into the center of a shallow pan and attaching beneath a tin ferrule, by which it is supported on top of a stake driven into the ground.

Destroy Infested Stalks.—If infestation of the plants has begun before note has been made of the presence of the moth in the field, then in addition to the use of the lights suggested above it would without doubt amply pay to go carefully over the field and cut off the infested stalks just below where the injury is apparent, and remove and destroy them (see p. 20). The infested plants will be recognized from their evident wilting, and this work can be done quite rapidly. When a man has become somewhat expert in recognizing the trouble, he will be able to remove all infested stalks from a row in about twice the time it would take him to walk the length of the same row. The object of this work is to stop the infestation before it becomes general; but it is evident that much watchfulness is required in detecting the attack in its incipiency. If the plants showing stalk-infestation are not too young, the removal of a part of the stalk does not materially hurt the plant as a tuber-producer. If the infestation is noted in an old plant, then the whole head may be removed a short distance beneath the surface of the ground a week or ten days before digging, thus effectively disposing of the worms, but in no way injuring the tubers (see p. 20). The necessity of destroying it at this time depends upon the fact that the worm may either come out from its burrow and pupate and then transform to the moth and be ready to multiply the damage many-fold, or may leave the stalk and work its way to the tubers in the ground.

Careful Hilling.—One of the most effective methods of preventing infestation of the tubers where flat culture is not imperative, is to be found in careful, compact hilling. Too often in our large potato fields where hilling is the practice, it is done so carelessly that many of the tubers are not covered completely, or if covered it is by a very thin and dry layer of earth. The potatoes that are not completely covered are attractive to the moth and are almost sure to be infected, while those that are thinly covered may be easily reached by the worm when it leaves the stalk.

If the covering over the potatoes in the hill is composed of lumpy material, the moth itself may find its way to the tubers, and infestation will follow. The greatest care should therefore be taken in this matter of hilling if the moth is about, as experiment has shown that where careless hilling is the practice great damage will ensue (see p. 18). When flat culture is practiced the same protection of the tubers should be accomplished by deep planting, supplemented, where necessary, by slight hilling at the last cultivation.

Avoid Exposure While Digging the Potatoes.—The potatoes should not be exposed to a possible visit from the moth while they are being dug. The moth at this time is ready for the potatoes and will find them if they are exposed for any great length of time, and especially if they are left exposed over-night. The practice of covering the newly-sacked potatoes with the potato tops to shade them, should also be avoided, and care should be taken to remove the sacked potatoes within, at most, four hours after digging. If such removal is impossible, then the sacks of potatoes should be stacked in the field and covered closely with a cloth of some sort to ward off possible visits from the moth (see p. 19).

Clean Up the Field After Digging.—The old heads and waste potatoes should be destroyed in the field after the crop has been removed, especially if the insect is at all in evidence, as this waste material offers a good breeding-place for the moth and may serve to carry the infestation forward to the next crop (see p. 14). The most satisfactory way to clean up a field of any large size is to turn sheep into it to pasture. The sheep are even more effective in their work than hogs, and seem to find every potato in the field, even going so far as to paw up any tubers that may have been missed in the digging and have remained covered with earth. In cases where a field has been flooded for two or three weeks the infestation seems to have been thoroughly destroyed. Any method that will destroy the waste potatoes on and in the ground will be effective, but this destruction must be accomplished if the ground is to be used for potatoes the ensuing year. Where this cannot be done, a rotation of crops is suggested as the only safe means of procedure, and it is effective because the worm feeds solely on solanaceous plants. Attention is here again called to the fact that the tubers used as seed must be free from infestation, as the moth will breed from such infested potatoes and will soon overrun the field.

Control of the Moth among Stored Potatoes.—The attack of the moth is the cause of great loss among stored potatoes, and it is probable that it is the damage done at this time that has been most observed. It is in the storerooms that surrounding conditions can be most easily controlled, but it is also here that the attack is most concentrated, and therefore at this time the work against it should be prosecuted with the greatest vigor.

Attention has been called to the use of carbon bisulfid (see p. 23) as an effective weapon against the moth when it is in the chrysalis form, and the careful use of this agent will undoubtedly stop the infestation among the stored tubers. To use the carbon bisulfid to any advantage the tubers must be placed in tight rooms or bins made in such a way that when the gas is being generated little or no leakage may occur. A bin made of tongue-and-groove lumber, with a top cover fitting quite closely, is to be considered the best for disinfecting small quantities. When larger quantities are to be treated, they may be piled in a tight room; the exact dimensions, the cubic space, of the room or bin must be known, as the amount of the carbon bisulfid used is determined by this cubic content.

It has been found in fighting insects in stored grain that one pound of the bisulfid to one thousand cubic feet of space is effective, but as potatoes are sacked this amount had better be increased to one and one half (1½) pounds, on account of the large air spaces occurring between the sacks. As far as our experiments go, they have shown that the gas generated diffuses thoroughly among sacked potatoes, and that the chrysalids are killed here quite as well as when the tubers are not sacked. Five treatments of the carbon bisulfid should be given to each lot of potatoes, in this order: A treatment when the tubers are first stored; a second, third, fourth, and fifth treatment at intervals of two weeks (see p. 24). In a room or bin that measures 10 feet each way, we have 1,000

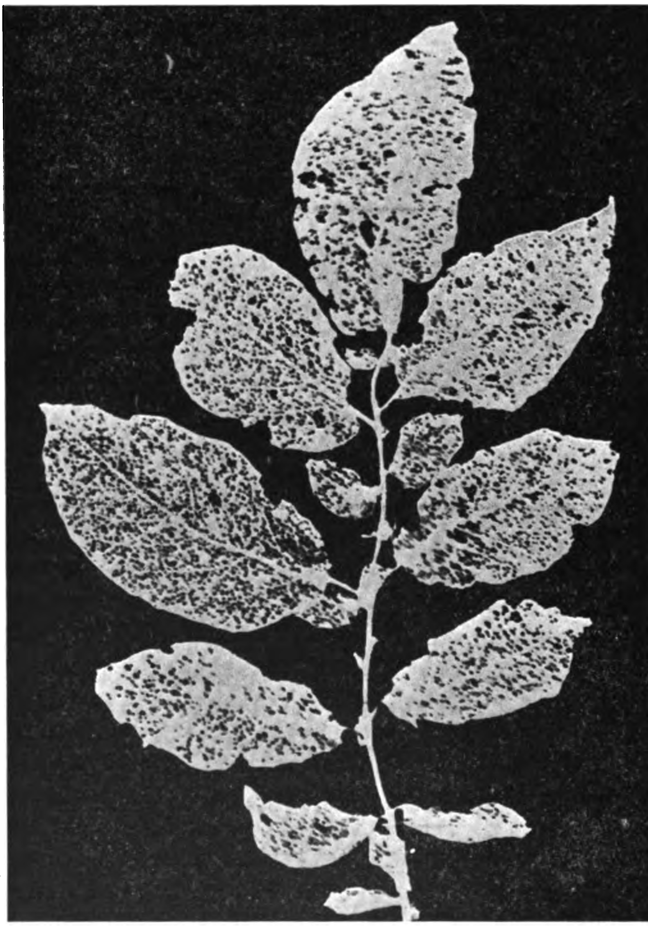


FIG. 8. The work of the Flea Beetle.

cubic feet of space, which will hold from 200 to 250 sacks of potatoes, and five thorough treatments of the contents will require 5 to 7½ pounds of the carbon bisulfid.

The material should be placed in shallow dishes on top of the potatoes, and then all should be tightly shut in. The liquid carbon bisulfid becomes a gas on being exposed to the air, and this gas being heavier than the air, sinks to the bottom and soon fills the spaces between the potatoes with its poisonous fumes. The gas is *highly inflammable*, and the greatest care must be exercised in handling it; be sure that no lights of any kind are near by at the time, or the results will be disastrous. The gas will kill all the chrysalids and all the adult moths present at the time, and will not injure the tubers.

OTHER PESTS.

In the course of this investigation of the moth *G. operculella* and its damages to the potatoes in California, certain other pests have been noted as causing more or less injury to this crop, and we briefly summarize these observations here.

Flea Beetles.—In the experiment plot on the Station grounds some damage was done to the plants by one of the flea beetles (*Epitrix subcrinita* Lec.), and in certain of the fields visited the damage done by another representative of the group, *E. hirtipennis* Mels., was quite large. These insects, which are true leaf-feeders, belong among the beetles in the family *Chrysomelidæ*. They are minute (1.5 mm. long), generally black or dark brown, ochreous-tinted beetles. The thoracic region and the elytra are regularly pitted. The pits are the seats of minute hairs (see Fig. 9). Their general appearance and their habit of jumping from their position on the leaf by means of their thickened hind legs, remind one strongly of a flea, whence the common name, flea beetles. They eat small round holes in the potato leaf, and when the attack is severe the leaves become so riddled with the punctures as to be able to function as leaves no longer. Figure 8 gives a good idea of the character of their work. The attack on the field from which the leaf here figured was taken was so severe that the value of the crop was reduced fully 50 per cent.

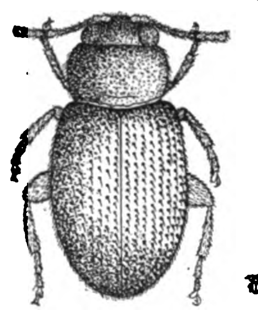


FIG. 9. *Epitrix hirtipennis* Mels. Right hand figure gives actual size of insect.

As stated above, this beetle is a leaf-feeder, and it can therefore be controlled by the use of Paris green, either dusted on the plant or used as a spray. The spraying material should be made up of one pound of pure Paris green to one hundred and fifty gallons of water, and may be cheaply and effectively applied to the plants by the use of a tank and spray pump on a wagon. The spray should be used as soon as the attack is observed, and, unless it is very violent, one application will probably be found sufficient to keep the beetles below the danger limit.

Stenopelmatus, incorrectly called Yellow Ground Cricket, Sand Cricket, Jerusalem Cricket, Common Beetle, and Potato Bug.

There are frequently noticed in the potatoes places where the tubers are bitten into as though mice had been gnawing them. These wounds are quite evident in some specimens, and render the tubers attacked unmarketable as a first-class product (see Fig. 6). The insect causing this damage is a large and clumsy member of the family to which the katydids belong. It has a large and horny head and a soft and heavy abdomen. Its movements are awkward and slow, and its color ranges from yellow to brown. It never has wings. It will be at once recognized from the figure No. 10. These insects seldom become numerous enough to do any large amount of damage, but nevertheless they should be killed, crushed, wherever found. They can be trapped by placing bits of board upon the ground in the field. The insects get beneath these boards and may be easily killed there.

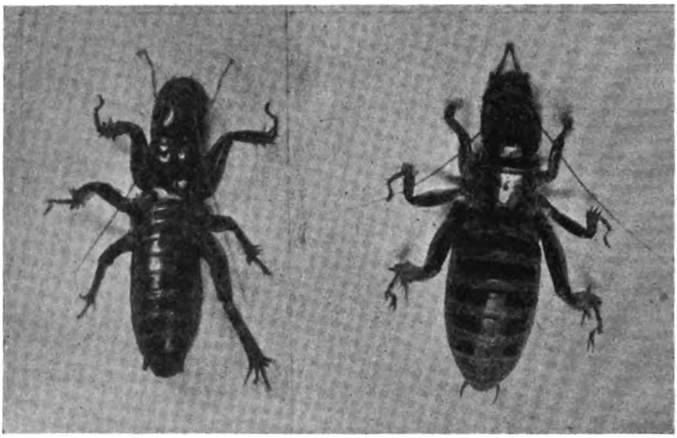
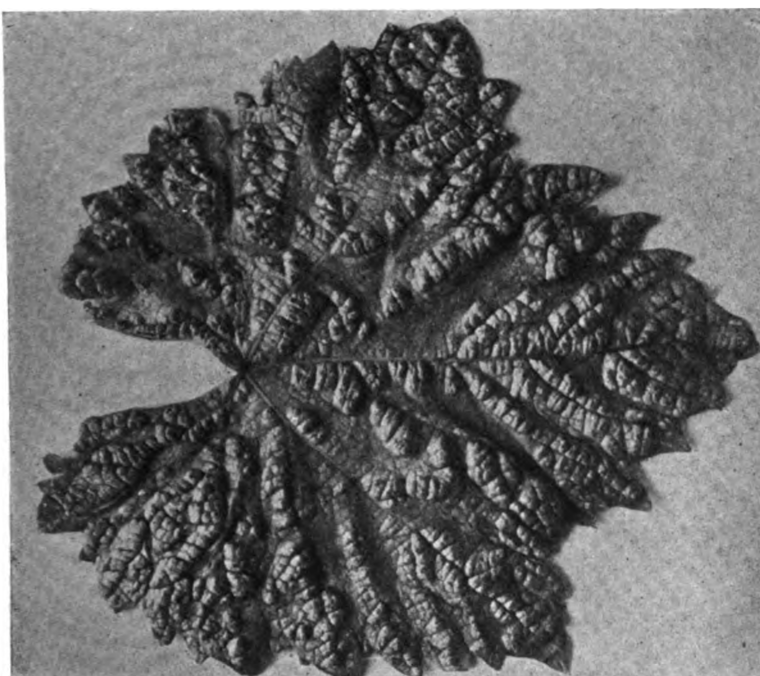


FIG. 10. Stenopelmatus.

UNIVERSITY OF CALIFORNIA—COLLEGE OF AGRICULTURE.
AGRICULTURAL EXPERIMENT STATION.
E. W. HILGARD, Director.

ERINOSE OF THE VINE.

BY FREDERIC T. BIOLETTI AND E. H. TWIGHT.



VINE LEAF AFFECTED WITH ERINOSE—UPPER SURFACE.

BULLETIN No. 136.
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ERINOSE OF THE VINE.

By FREDERIC T. BIOLETTI and E. H. TWIGHT.

For the last five years specimens of vine leaves affected with Erinose have been received at the Agricultural Experiment Station in increasing numbers. The disease is evidently spreading rapidly throughout the vineyards of California, and the number of inquiries received concerning it makes it desirable that an account of it, available for general distribution, should be published.

Erinose is a disease of the vine characterized by swellings on the upper surface of the leaves, and corresponding depressions on the lower surface. These swellings, when numerous, cause considerable deformation of the leaves, but not the change of color to yellow or brown which is characteristic of most fungous diseases. Even very badly-affected leaves retain almost their normal green color until late in the season. The depressions on the under side are coated with a thick felt-like covering, which, at first pure white, gradually turns rusty and finally becomes dark brown. Generally, the swellings and corresponding depressions are isolated and few in number on the affected leaves, but in severe cases they are numerous enough to become confluent, and the whole lower surface is then completely hidden by the felt-like covering. Occasionally, indeed, the felt-like material extends to the upper surface in narrow strips bordering the veins, and may even be found on the petioles and flower clusters.

Most of the specimens received at the laboratory were sent under the impression that they were attacked by a fungus, and, in fact, the coating has a strong superficial resemblance to some fungous growths. A microscopic examination shows, however, that it consists of a mass of hypertrophied hairs or abnormal outgrowths of the epidermal cells of the leaf. They are larger, more abundant, and more persistent than the normal leaf-hairs of the leaf, and differ also in being often branched and usually unicellular. This abnormal growth, in common with similar growths found on other plants, is called an *erineum*, from a Greek word meaning woolly. This is the derivation of the word Erinose, which means woolly disease, a very appropriate name. The erinea of leaves were formerly supposed to be of fungous origin, but are now known to be due to the attacks of minute mites. The stings or punctures of these mites exert a stimulating effect upon the epidermal

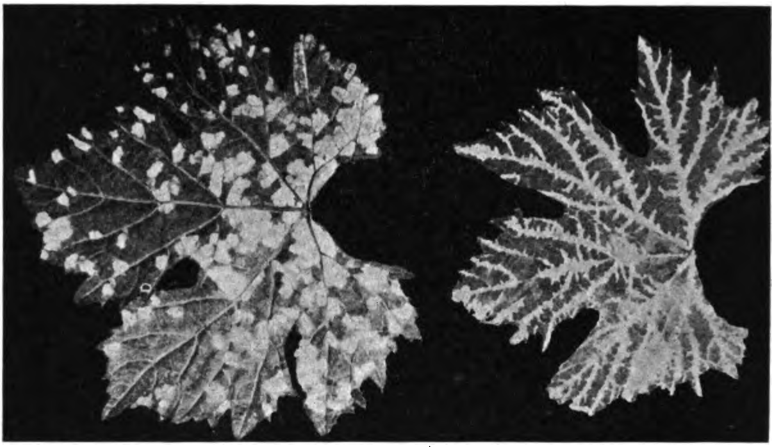


FIG. 1.

White patches of erineum on the lower surface of a leaf as they appear in the earlier part of the season.

Upper surface of a badly affected leaf, showing how the erineum extends to the upper surface in severe cases.

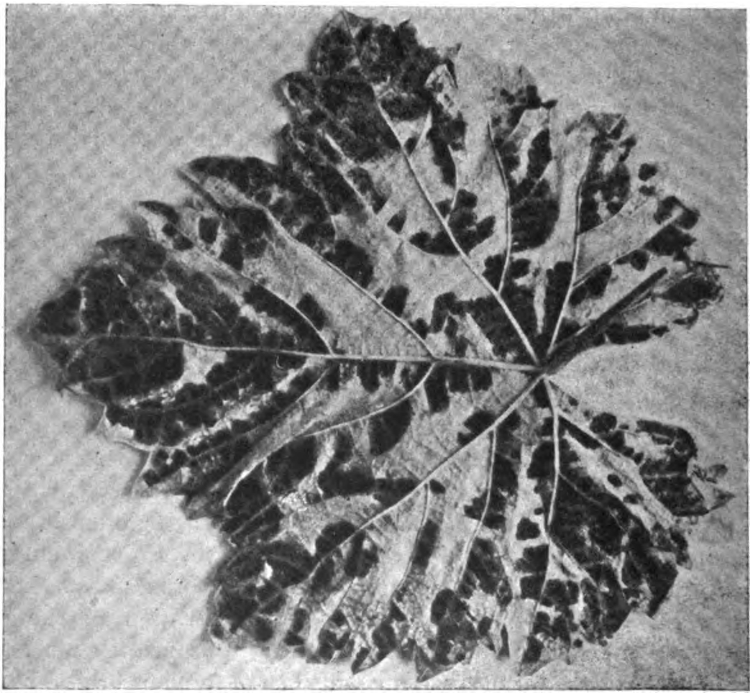


FIG. 2. Lower surface of the leaf shown in the frontispiece, showing the brown patches of erineum as they appear in autumn.

cells of the leaf, which causes them to grow out into the abnormal hair-like processes already described. The mite causing Erinose of the vine is known as *Phytoptus vitis*, and is related to the mites causing a similar disease of the walnut and the leaf-blister of the pear, both of which are very common in California.

The *Phytoptus vitis* is not a true insect, but a mite or acarid belonging to the class of Arachnida to which belong also spiders, scorpions, ticks, and our common clover-mite or red spider so destructive to fruit trees. These mites are extremely minute, and only a practiced eye can perceive them, among the tangled mass of erineum on the leaf, by the aid of an ordinary hand magnifier, and then only with great difficulty. To see them easily they must be separated and examined with a microscope magnifying at least fifty diameters. To isolate them the method recommended by Valery Mayet is probably the best. With a sharp knife scrape off a quantity of the erineum into a watch-glass. As soon as the hairs begin to dry-up, the mites abandon them and may be found congregated in numbers around the edge of the watch-glass. The form which we usually find upon the vine leaves is an elongated, flexible, almost cylindrical, worm-like larva about $\frac{1}{150}$ of an inch in length and $\frac{1}{800}$ of an inch in diameter. The mite is furnished at one end with four legs, and is armed with two piercing organs, with which it attacks the leaves. Notwithstanding its small size and apparently awkward shape it is very lively in its movements and shows remarkable vitality. It has been known to survive an immersion of forty-eight hours in water, and has been seen to lay eggs after remaining in glycerine for twenty-four hours. Like other members of the group, the *Phytoptus vitis* passes through several forms, and, besides the common larva already described, has at different stages of its metamorphosis six and eight legs, the latter being the perfect form. The four-legged larvæ pass the winter under the rough bark of the vine or among the scales of the buds, many of them without change of form, while others surround themselves with a kind of transparent cyst.

Amount of Injury.—Erinose was formerly considered to be a very serious disease of the vine, owing to the fact that its effects were confused with those of the powdery mildew. It is only in very exceptional cases that it is, alone, capable of doing serious injury to the vine or its crop. When accompanying oidium or drought it may, however, perceptibly increase the damage due to these causes. When very abundant, it may seriously interfere with the growth of young vines, but, according to Mayet, never damages old vines, except by interfering slightly with the ripening of the canes or at most causing an almost imperceptible diminution of crop. All varieties of vines are not equally attacked. According to Ravaz, certain American species such as Berlandieri,

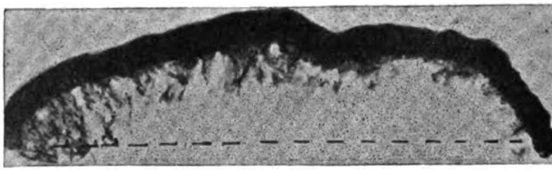


FIG. 3. Photomicrograph of a cross-section through an affected area of a vine leaf, showing the erineum in the depression on the lower surface. The broken line shows the position that this portion of the leaf would have occupied had it not been attacked by the mites.

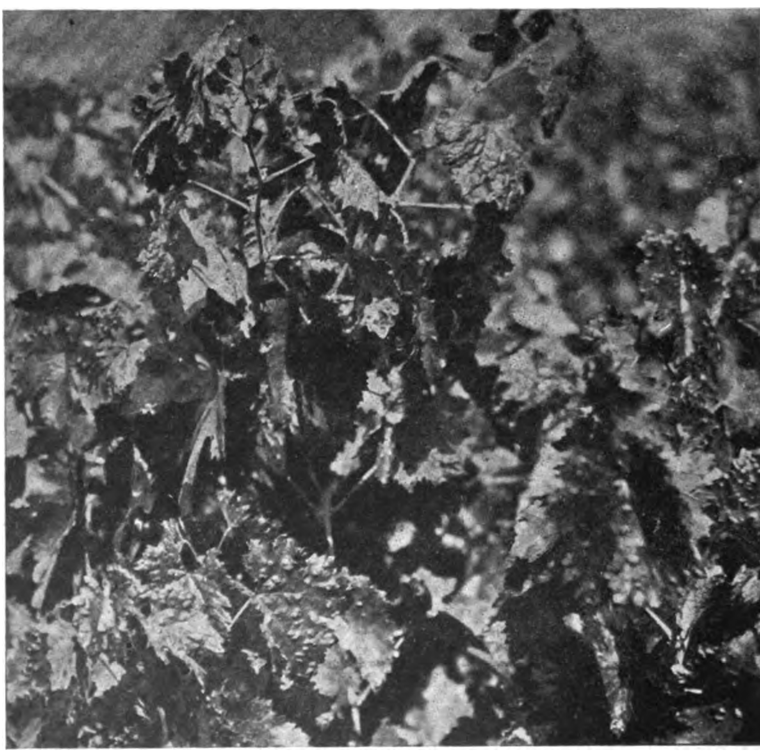


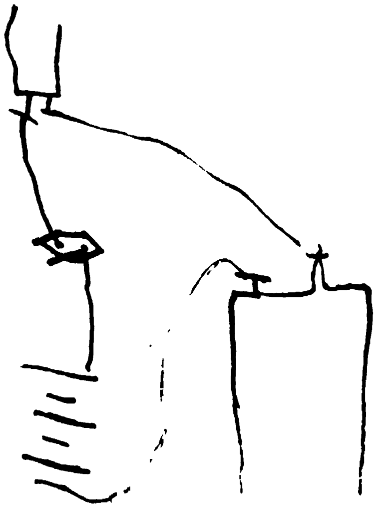
FIG. 4. Vine affected with Erinose.

Mustang, Cinerea, Cordifolia, and Scuppernong are immune. All varieties of vinifera are susceptible, but not equally. Of varieties cultivated in California, Sauvignon, Sirah, Marsanne, and Gamay Teinturier are said by Ravaz to be little subject to attack, while Aramon, Cinsaut, and Frontignan (Small Muscatel) are very susceptible. The worst cases so far observed in California have been on Flame Tokay and Mission, but it has been found also on other varieties, among them Zinfandel and Muscat.

Methods of Treatment.—Since sulfuring the vines for the treatment of oidium has become general in France there has been little trouble with Erinose. The phytoptus seems as sensitive to the fumes of sulfur as the red spider, and several sulfurings during the late spring and early summer are recommended for the control of the mite. The only vineyards which have been found badly affected in California are those in which little or no sulfuring has been done, or those where the growth of foliage has been so luxuriant as to prevent the evaporation of the sulfur by the sun. In the latter cases the vines are so strong that they practically receive no harm from the disease. In severe cases a winter treatment of the vine stumps is practiced in France. This treatment consists in pouring about one quart of boiling water over the stump. For very large stumps a somewhat greater amount of water is used, and for smaller vines a proportionate amount. This method is said to be very efficacious, and with the portable boilers constructed for the purpose two men can treat from 1500 to 2000 vines per day. Cuttings taken from affected vines for the purpose of rooting or grafting may be thoroughly disinfected by placing them in hot water (122° F.) for ten minutes. If this is done carefully all the mites and their eggs will be destroyed without injury to the cuttings.

Distribution in California.—The first specimens of Erinose received by the Experiment Station were sent from Windsor, Sonoma County, in 1896. The next year, affected leaves were received from Healdsburg and Dry Creek, in the same county. All these cases were upon Mission vines. Since then, specimens of the disease have been received as follows: 1898, from Kenwood, Sonoma County, on Zinfandel; 1899, from Lytton and Sebastopol, Sonoma County; 1901, from Martinez, Contra Costa County, Roseville, Placer County, Florin and Folsom, Sacramento County, Cloverdale, Sonoma County, and from Dinuba, Tulare County.

A short account of this disease was given in the fifth biennial report of the California State Board of Horticulture, on page 50, where its occurrence is noted at Florin, Sacramento County.



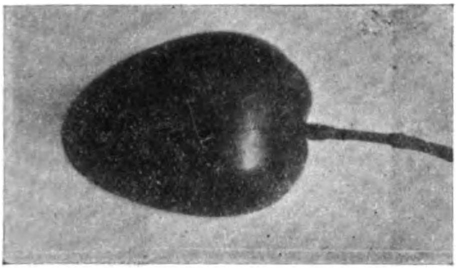
UNIVERSITY OF CALIFORNIA—COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

E. W. HILGARD, Director.

PICKLING RIPE AND GREEN OLIVES.

BY FREDERIC T. BIOLETTI.



Natural size.

Reduced to one third.

SEVILLANO OLIVE.

BULLETIN No. 137.

(Berkeley, December, 1901.)

SACRAMENTO:

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1901.

PICKLING RIPE AND GREEN OLIVES.

By FREDERIC T. BIOLETTI.

The continuous increase in the crop of olives in the State, due to the coming into bearing of young orchards during the past few years, has resulted in a growing demand for information on the subject of olive-growing, and especially on the treatment of the crop in oil-making and pickling. It was to meet this demand in a general way that Bulletin No. 123, "Olives," was issued in 1899. The methods of pickling recommended in that bulletin seem generally to have given satisfaction, but many complaints have been received of failure where these methods are said to have been followed. Most of the cases of failure, when more closely investigated, were found to be due, not to any defect in the method as given in the bulletin, but to some neglect to closely follow the recommendations given. Usually some important step had been omitted or some precaution neglected. The most common mistakes have been neglect of frequent changes of water, the use of impure water, the omission of a thorough disinfection of the pickling vats with boiling water, and failure to adapt the strengths of lye-and-salt solution to olives of various grades and degrees of ripeness. In some cases, however, where the method seems to have been followed faithfully, the pickles have failed to keep long enough to be marketed, especially when shipped to Eastern points, where they have been subjected to wide changes of temperature.

EXPERIMENTS WITH PICKLING RIPE OLIVES.

In order to throw light on the causes of these latter failures, and to attempt to find some solution of the difficulties, it was determined to undertake a series of experimental picklings. For this purpose, a quantity of ripe olives was kindly donated to the Experiment Station by Mr. John Rock, of the California Nursery Company, at Niles, Alameda County. The olives sent were particularly suitable for the purpose, as they consisted of several varieties and were nearly all dead-ripe, in fact, many of them were considerably over-ripe, and as they had been picked and shipped without any special precautions, they were considerably bruised when received. As the water at Berkeley available for the purpose of pickling was far from the purest, and was in fact contaminated to a considerable extent with organic matter and micro-organisms, the conditions were very favorable for the investigation of some of the main difficulties encountered in preserving olive pickles.

The olives were received on February 16, 1899, and were of the following varieties: Gordal, Uvaria, Columbella, Regalis, Rubra, Mission, Manzanillo, Nevadillo Blanco, forty pounds of each; Picholine d'Aix, Rouget, twenty pounds of each; Sevillano, ten pounds; Oliviere, four pounds; Salliern, Da Salere, Pigale, two pounds of each.

On account of the over-ripe, soft, and bruised condition of most of the fruit, it was determined to use a weak lye-solution, and in most cases to use salt from the beginning of the process. The lye-solution was made up by dissolving 1.9 oz. of lye in one gallon of boiled water, that is at the rate of 1.5%. An analysis of the lye-solution showed it to contain 1.4% of pure lye, the difference of one-tenth of a per cent being due to impurities and to lack of strict accuracy in measuring the water. The measurement, however, was accurate enough for practical purposes.

The olives were sorted over before being pickled, in order to have them of fairly uniform size in each lot. This is very necessary for the best results, both on account of the difference of time needed to extract the bitterness of fruit of different sizes, and of the preference of the consumer for pickles of uniform appearance. The small olives were therefore rejected, but no attempt was made to eliminate over-ripe or bruised fruit. Any which showed signs of mold or decay were of course thrown out. As the olives were used very soon after picking, however, there were very few of the last kind. Earthenware jars were used for pickling, and the olives were kept submerged by means of floating wooden covers. The jars had a capacity of four gallons each, except the jar in which the Sevillano was treated, which was smaller, on account of the small amount of fruit available. Eight experiments were made, each with a different variety. A full account of the method pursued and of the course of the experiments is given in the following pages under the heading of the variety employed.

The questions which these experiments were devised to answer were: 1. Could large, over-ripe, bruised olives, which were otherwise in good condition, be used to produce wholesome marketable pickles? 2. Could such pickles be preserved in good order for a reasonable length of time? Incidentally, some information was obtained as to the relative suitability of the various varieties for the production of marketable ripe pickles.

1. GORDAL. Large, very even in size, dark reddish purple, good condition, very ripe.

Feb. 17, 1899, 5 P. M. Covered with a solution of 1.4% lye and 2% salt.
" 18, 9 A. M. Rinsed and left in water four hours.
" 18, 1 P. M. Put in 2% salt brine; olives rather soft.
" 19, 1 P. M. Put in fresh 2% brine; olives firmer, but bitter.
" 21. Put in 3% salt brine.
" 24. Put in 4% salt brine.
" 28. Put in 6% salt brine.
Mar. 3. Put in 6% salt brine; olives still slightly bitter.
" 7. Put in 8% salt brine; bitterness almost gone.
" 28. Put in 12% salt brine and divided into four lots:
A. Placed in an earthenware jar, in which the pickles were kept submerged by means of a floating wooden cover.
B. Placed in a fruit-preserving jar and untreated.
C. Placed in a fruit-preserving jar and heated to 80° C. (176° Fahr.) once.
D. Placed in a fruit-preserving jar and heated to 80° C. (176° Fahr.) three times on successive days.
Oct. 30. Olives in open jar (A) in perfect condition; better flavored than the Mission and of tenderer texture, though sufficiently firm; too light in color.
Nov. 1. Olives in lot A divided into three lots, as follows:
E. Placed in a fruit-preserving jar and left untreated.
F. Placed in a fruit-preserving jar and heated to 80° C. (176° Fahr.).
G. Placed in a fruit-preserving jar and after pouring off the brine and filling up with water heated to 80° C. (176° Fahr.).
Jan. 5, 1900. B and D of the first bottling showed mold on top, but all the others had kept perfectly.

Result in nearly 32 months. Oct. 5, 1901.

Lot B (not heated) soft and spoiled.

Lot E (not heated) soft and, though not spoiled, was much inferior to the heated samples in texture and flavor. There was no mold nor scum on top of the liquid, but a slight acidity showed the effect of fungous or bacterial fermentation.

Lot D showed a little mold on top of the liquid, but the flavor of the olives was unaffected.

The other heated samples were all in good condition, of good flavor, and showed no scum or mold and no discoloration of the brine. Lot G was in just as good order as the others, and was superior in that it contained less salt. The specific gravity of the brine indicated only 5% of salt, owing doubtless to absorption by the fruit.

2. PICHOLINE D'AIX. In fair condition, very uneven in size, many small unripe olives, but the rest very large and fine, dark reddish-black. Many of the ripe olives were badly bruised.

Feb. 17, 1899, 5 P. M. Covered with a solution of 1.4% lye and 2% salt.
" 18, 1 P. M. Rinsed and put in 2% brine; fairly firm, but variable in color.
" 19, 2 P. M. Put in 2% brine; very bitter, many blistered.
" 21. Put in 2% brine; still very bitter.
" 24. Put in 2% brine; still very bitter; very firm.
" 28. Put in 2% brine; still bitter.
Mar. 3. Put in 4% brine.

Mar. 7. Put in 6% brine.
" 16. Put in 8% brine.
" 25. Put in 12% brine; placed in an open earthenware jar, in which the olives were kept submerged by means of a floating wooden cover.
Oct. 30. Olives in good condition, firm and well flavored; many show blisters, but they have kept perfectly. The color is rather light, the stone large, and the skin tough.
Nov. 1. Divided into three lots and placed in fresh 12% brine in glass fruit-preserving jars, and treated as follows:
A. Sealed without further treatment.
B. Sealed and heated to 80° C. (176° Fahr.).
C. The brine replaced with water, the jar sealed and heated to 80° C. (176° Fahr.).
Jan. 5, 1900. All the samples have kept perfectly.

Result in nearly 32 months. Oct. 2, 1901.

Lot A has a scum on top of the liquid, but the olives are firm and good, though somewhat inferior in flavor to lots B and C, on account of a slight acidity, due probably to a slight fermentation. B and C have kept perfectly and are of excellent flavor. C is the best, on account of the smaller amount of salt it contains. This variety is inferior in flavor and texture to the Manzanillo and the Gordal, but equal to the Mission. It is inferior to the Mission in color, but somewhat darker than the Gordal.

3. Regalis. In fair condition, varying in size from medium to large, color varying from greenish-white to red and red-purple (similar to Columbella in color, but of larger size); shows a good deal of sooty mold.

Feb. 17, 1899, 5 p. m. Washed and put in a solution of 1.4% lye and 2% salt.
" 18, 1 p. m. Liquid which shows .25% lye, replaced with a 2% brine. The olives are firm, but generally light and very uneven in color.
" 19. Put in 2% brine. Color very varied.
" 21. Put in 3% brine. Bitterness nearly gone.
" 24. Put in 4% brine.
" 28. Put in 4% brine. A few olives slightly bitter still.
Mar. 3. Put in 6% brine.
" 7. Put in 8% brine.
" 16. Put in 12% brine.
" 28. Divided into four lots, as follows:
A. Placed in open earthenware jar, in which the olives were kept submerged by means of a floating wooden cover.
B. Placed in a glass fruit-preserving jar and sealed.
C. Placed in a glass fruit-preserving jar, sealed and heated to 80° C. (176° Fahr.).
D. Placed in a glass fruit-preserving jar, sealed and heated to 80° C. (176° Fahr.), three times on successive days.
Oct. 30. Olives in the open jar (A) in good condition, firm, and of good flavor. Very varied in color, from white to dark, almost black. Sample A was divided into three lots and treated as follows:
E. Placed in glass fruit-preserving jar in 12% brine, and sealed.
F. The same as E, but heated to 80° C. (176° Fahr.) after sealing.
G. The same as F, but placed in water instead of brine.
Jan. 5, 1900. All the lots have kept well.

Result in nearly 32 months. Oct. 10, 1901.

Lot B (not heated) is soft, moldy on top, flavor quite spoiled.

Lots C and D have kept well and are of good flavor and texture, but are too light colored. D (heated three times) has a very dark-colored brine.

Lot E (not heated) shows a slight scum on top of the liquid, but the olives are uninjured except for a slight acidity due to the growth of molds or bacteria. The olives are yellow and even in color, the brine clear and colorless.

Lot F is in perfect condition and of excellent flavor, firm but tender, of an even dark gray color, but a little too salty. The brine is clear, but dark colored.

Lot G has kept just as well as F, and the smaller amount of salt makes it preferable. The color of both olives and liquid is lighter than that of F.

This variety is an excellent one for ripe pickles, with the exception of its lack of color.

4. MANZANILLO. Bruised and over-ripe, but otherwise in good condition, of good size, but not of such fine appearance or so even in size and quality as the Gordal.

Feb. 17, 1899, 5 P. M. Put in a solution of 1.4% lye and 2% salt.
" 18, 1 P. M. Rinsed and put in 2% salt brine. The color is a uniform deep black, with the exception of a few imperfectly ripe olives, which are a little green on one side; they are all of good flavor and fairly firm; still a little bitter.
" 19. Put in 2% brine; the ripest fruit has lost its bitterness.
" 21. Put in 2% brine; many olives are still very bitter.
" 24. Put in 2% brine; many olives still bitter.
" 28. Put in 2% brine; still bitter.
Mar. 3. Put in 4% brine; bitterness nearly gone.
" 7. Put in 8% brine.
" 16. Put in 12% brine.
Oct. 30. In fine condition; deep black and of excellent flavor; a little softer than the Mission.
" 31. Divided into three lots, and treated as follows:
A. Put in glass fruit-preserving jar and sealed (brine 12%).
B. The same as A, but heated to 80° C. (176° Fahr.) after sealing.
C. The same as B, but covered with a layer of paraffin before sealing and heating.
Jan. 5, 1900. All the samples appear good and show no mold on top.

Result in nearly 32 months. Oct. 7, 1901.

Lot A. A heavy scum on top of the liquid; olives soft, acid, and slightly rancid, of poor quality.

Lot B. Better than A, but not so good as C.

Lot C. Has kept perfectly; of excellent flavor and texture and deep uniform black color.

The Manzanillo is the best pickle of the series, and is equaled in flavor and texture only by the Gordal, which is inferior in color.

5. Mission. In good condition; firm and less over-ripe than the Manzanillo.

Feb. 17, 1899, 5 P. M. Put in a solution of 1.4% lye and 2% salt.
" 19, 1 P. M. Rinsed and put in 2% salt brine; olives all uniformly black and fairly firm.
" 21. Put in 2% brine.
" 24. Put in 2% brine; still bitter.
" 28. Put in 2% brine; still a little bitter.
Mar. 3. Put in 4% brine.
" 7. Put in 8% brine.
" 16. Put in 12% brine.
Oct. 30. In good condition; black, firm, and of good flavor; a little mold around the edge of the cover, but the olives unaffected.
" 31. Divided into three lots, and treated as follows:
A. Put in glass fruit-preserving jar and sealed (brine 12%).
B. The same as A, but heated to 80° C. (176° Fahr.) after sealing.
C. The same as B, but heated to 90° C. (194° Fahr.). The bottle cracked during the heating, and the sample was lost.
Jan. 5, 1900. Both lots A and B seem to have kept well.

Result in nearly 32 months. Oct. 8, 1901.

Lot A shows a scum on top of the liquid, and the olives have a faint acid taste, due to bacterial or fungous fermentation; the quality is fair but not nearly equal to B, and the color is lighter.

Lot B is of excellent quality and in perfect condition; firm but not tough, dark brownish-black; the flavor is clean and good, but not quite equal to that of the Gordal or the Manzanillo.

6. Columbella. In fair condition, some of the olives shriveled; of good size, averaging a little smaller than the Regalis.

Feb. 18, 1899, 8:30 A. M. Put in a solution of 1.4% lye.
" 18, 3 P. M. Rinsed and put in a solution containing 1.4% lye and 2% salt.
" 19, 12 M. Put in 2% brine; still bitter and taste of lye.
" 21. Put in 2% brine.
" 24. Put in 2% brine; taste of lye, but little bitterness.
" 28. Put in 4% brine; not bitter.
Mar. 3. Put in 6% brine.
" 7. Put in 8% brine.
" 16. Put in 12% brine.
" 28. Divided into four lots, as follows:
A. Placed in an open earthenware jar, in which the olives were kept submerged by means of a floating wooden cover.
B. Placed in glass fruit-preserving jar, and sealed.
C. The same as B, but heated to 80° C. (176° Fahr.) after sealing.
D. The same as C, but heated three times to 80° C. (176° Fahr.) after sealing.
Oct. 30. Lot A (in open jar) in good condition, firm, sound, and of good flavor and texture; color light and somewhat spotted.
" 31. Divided A into three lots, as follows:
E. Put in glass fruit-preserving jar, and sealed.
F. The same as E, except that it was heated to 90° C. (194° Fahr.) after sealing.
G. The same as F, except that it was covered with a layer of paraffin before sealing and heating.
Jan. 5, 1900. Lot B is covered with a thick mold; the others have kept perfectly.

Result in nearly 32 months. Oct. 10, 1901.

Lot B (unheated) moldy and spoiled.

Lots C and D (heated) firm, sound, and of good flavor.

Lot E (unheated) shows no scum on top and has kept fairly well; it has less of the acidity that characterizes most of the other unheated samples, but it is inferior in flavor to C, D, F, and G.

Lots F and G are firm, sound, and of good flavor, somewhat darker in color than E, which is light yellow; the brine is also darker in color than that of E.

7. ROUGET. In good condition, firm, ripe, but not over-ripe, uninjured by frost or rain; rather small, but larger than the Rubra, and nearly as large as the Nevadillo.

Feb. 18, 1899, 8:30 A. M. Put in 1.4% lye-solution.
" 18, 3 P. M. Put in 2% salt brine.
" 19, 12 M. Put in a fresh 2% salt brine. The olives have a sweetish taste and very little bitterness or taste of lye; the flesh is soft.
" 20. Put in 4% brine.
" 24. Put in 4% brine.
" 28. Put in 4% brine.
Mar. 3. Put in 6% brine.
" 8. Put in 8% brine.
" 16. Put in 12% brine; placed in open earthenware jar, in which the olives were kept submerged by means of a floating wooden cover.
Oct. 30. Perfectly sound, firm, and of a dark gray color. The flavor is not very good—too oily.
Nov. 1. Divided into three lots, and treated as follows:
A. Put in a glass fruit-preserving jar, and sealed.
B. The same as A, except that it was heated to 80° C. (176° Fahr.) after sealing.
C. The same as B, except that it was covered with a layer of paraffin before sealing and heating.
Jan. 5, 1900. All the lots have kept well.

Result in nearly 32 months. Oct. 10, 1901. All the samples have kept well, except that A has a scum on top of the liquid. The heated samples are darker-colored and slightly better in flavor than A, but none of them are very good. The olives are tough and of poor flavor; the variety is evidently unsuited for pickling.

8. SEVILLANO. Extremely large and of fine appearance, but over-ripe and in poor condition. Many have been injured by being pecked by birds. The best were sorted out and pickled.

Feb. 17, 1899, 5 P. M. Put in a solution of 1.4% lye and 2% salt.
" 18, 9 A. M. Rinsed and put in 2% salt brine. The olives are of a uniform deep black, but very bitter and rather soft.
" 19. Put in 2% brine; still bitter, some soft but most are firm.
" 20. Put in 2% brine.
" 21. Put in 4% brine.
" 23. Put in 4% brine; still a little bitter.
" 28. Put in 6% brine; a very little bitterness left.

Mar. 3. Put in 8% brine.
" 7. Put in 12% brine.
" 16. Divided into three lots, and treated as follows:
A. Put in a glass fruit-preserving jar and sealed.
B. The same as A, but heated to 70° C. (158° Fahr.) for 15 min. after sealing.
C. The same as B, but heated to 70° C. (158° Fahr.) for 15 min. three times on successive days.
Jan. 5, 1900. Lots A and B show mold on top of the liquid. Lot C has kept perfectly.

Result in nearly 32 months. Oct. 10, 1901.

Lot A quite spoiled.

Lot B shows a little mold on top, but the olives are firm and edible, though not of so good flavor as lot C.

Lot C has kept perfectly and the olives are firm and of very good flavor and dark color.

Over-ripe Olives.—These experiments show that even soft, over-ripe olives may be successfully pickled by proper modifications of the lye-and-salt method, even when the fruit has been somewhat carelessly handled before pickling and when the water used is not of the purest. The main precautions in such cases are to use a certain amount of salt from the beginning of the process, and to watch carefully for the first appearance of scum or slime on top of any of the liquids in which the olives are immersed. On the appearance of the slightest of these signs of fermentation, the solution must be changed and the receptacle thoroughly disinfected with *boiling* water. The salt hardens the flesh and makes it more resistant to fermentative organisms which exist in the water, and at the same time the antiseptic properties of the salt, even when used in such small proportions as 2%, are probably of use in delaying the increase of these organisms, molds, and bacteria. All the samples, with the exception of the Sevillano, kept without perceptible deterioration for eight months in open jars after pickling, although they were unprotected from the air except for a floating wooden cover. A ring of mold formed around the edge of the cover, but there was no perceptible injury to the flavor of the pickles, except for a slight moldiness in the taste of the Sevillano.

SUMMARY OF THE RESULTS OF VARIOUS METHODS OF KEEPING THE PICKLED OLIVES.

1. Seven samples (Gordal, Picholine, Regalis, Manzanillo, Mission, Columbella, and Rouget) were placed in 12% brine in open earthenware jars with floating wooden covers. A little mold formed around the edge of the floating cover, but the pickles were uninjured in flavor, texture, or color at the end of eight months.

2. Four samples (Gordal, Regalis, Columbella, and Sevillano) were placed in 12% brine in hermetically sealed fruit-preserving jars immediately after pickling. All except the Regalis were very moldy at the

end of eleven months, and they were all quite spoiled at the end of thirty-two months.

3. Seven samples (Gordal, Picholine, Regalis, Manzanillo, Mission, Columbella, and Rouget) were kept in open jars for eight months (see No. 1) and then placed in fresh 12% brine in sealed fruit-preserving jars. When examined at the end of eleven months (three months after sealing) they were all sound, but at the end of thirty-two months the Manzanillo was almost spoiled, the Gordal much deteriorated, and the others though still edible were much injured in flavor and appearance.

4. Three samples (Gordal, Regalis, and Columbella) were placed in 12% brine in sealed fruit-preserving jars and heated to 80° C. (176° Fahr.) immediately after pickling. They were all in perfect condition when examined at the end of thirty-two months. A sample of Sevillano, which was treated in the same way except that it was heated to only 70° C. (158° Fahr.), had deteriorated slightly but was still quite edible, while a corresponding unheated sample was quite spoiled.

5. Seven samples of the pickles kept in open jars for eight months (see No. 1) were placed in sealed fruit-preserving jars at the end of the eight months and heated to 80° C. (176° Fahr.). All the samples kept perfectly with the exception of the Manzanillo, which showed a slight deterioration in flavor.

6. Three samples (Gordal, Picholine, and Regalis) of the pickles kept in open jars (see No. 1) were placed in pure water in sealed fruit-preserving jars at the end of the eight months and heated to 80° C. (176° Fahr.). All kept perfectly and were preferable to all the others at the end of thirty-two months, on account of the smaller amount of salt that they contained. The specific gravity of the brine at the end of the thirty-two months indicated only 5% salt.

7. Three samples (Gordal, Regalis, and Columbella) were heated to 80° C. (176° Fahr.) three times on successive days in sealed fruit-preserving jars and kept perfectly, but showed no superiority to those heated only once. One sample (Sevillano) heated in the same way three times to 70° C. (158° Fahr.) also kept perfectly, and was superior at the end of thirty-two months to a sample of the same variety heated only once to 70° C. (158° Fahr.).

8. Three samples (Manzanillo, Columbella, and Rouget) were placed in sealed fruit-preserving jars and covered with a layer of paraffin before being heated to 80° C. (176° Fahr.). They all kept perfectly, but the paraffin was objectionable, and though the Manzanillo sample seemed to have kept a little better than the heated sample without paraffin, a little longer or higher heating would doubtless be equally effective, and the troublesome and unsightly paraffin would not be needed.

In a general way it may be said that all of the eleven *unheated* samples kept in fair to good condition for eleven months, but that they were all more or less spoiled before the end of thirty-two months; and, on the other hand, that all the twenty samples *heated to 80° C.* (176° Fahr.) kept perfectly to the end of thirty-two months, and were quite as good if not better than when first made, with the exception of one sample, which had deteriorated slightly.

It may be concluded from this that heating to 80° C. (176° Fahr.) is a sufficient means of preserving ripe olives, even in weak brine, for an indefinite period in hermetically sealed glass jars, provided that they are exposed to no greater changes of temperature than occur in an ordinary room in Berkeley. Whether they would have kept so long without deterioration if exposed to the trying conditions of shipment to Eastern points is doubtful; but there is no doubt that they would have kept much better and longer, even under those conditions, than olives treated in the usual way, and there is every reason to believe that a slightly higher heating, say to 90° or 95° C. (194° or 203° Fahr.), would have made them perfectly secure in any climate.

That this heating could be applied successfully to *olives in wooden casks* seems highly probable. A method which would doubtless be effective would be to place the pickles in a 8% or 10% brine in casks previously sterilized by steaming, and then to heat them with a current of pressure steam conducted directly into the brine. It would not be difficult to devise means for preventing the superheated steam from coming directly in contact with the olives and to keep them in constant movement in order to guard against too much heating of a part of the contents of the cask until they were all heated to a uniform temperature of 90° C. (194° Fahr.). Properly pickled olives are, moreover, very resistant to heat, and even 100° C. (212° Fahr.) continued for half an hour has no perceptible effect on their texture or flavor, unless it be a slight improvement of both.

The only objection to heating noted was that it causes a diffusion of the coloring matter of the olives into the brine, so that after heating the olives were lighter-colored and the brine darker than before. This diffusion, however, takes place in time even with unheated olives, and at the end of thirty-two months the unheated olives were in most cases actually lighter-colored than those which had been heated.

RELATIVE QUALITY OF THE VARIETIES TESTED.

All the varieties experimented with made pickles of excellent quality with the exception of the Rouget, which was small, greasy, and of a sweetish disagreeable flavor. Some of the varieties, however, were superior to others in flavor and texture, others in size and shape, and others in color. In the following lists they are arranged in the order of their merit in these various particulars:

Flavor and texture: Gordal, Manzanillo, Columbella, Regalis, Mission, Sevillano, Picholine.

Color: Manzanillo, Sevillano, Mission, Picholine, Gordal.

Size: Sevillano, Picholine, Manzanillo, Gordal, Mission, Regalis, Columbella.

In arranging these varieties in order of excellence, account must be taken of whether we mean excellence from the market point of view or from that of the connoisseur. The market demands two qualities above all others—large size and deep color. The typical olive shape is also desirable, but flavor and texture seem to be of secondary importance. For this reason no small olive will command a good price, and light-colored varieties such as the Columbella and Regalis, though of superior quality, will bring lower prices than the Mission or Picholine. The Manzanillo combines the qualities of large size, dark color, and delicate flavor and texture in a higher degree than any other variety; but its peculiar short, apple shape is considered less desirable by buyers than the typical olive shape of the Sevillano and Mission. For these reasons the relative excellence of the varieties tested would seem to be that indicated by their position in the following lists:

For home use: Gordal, Manzanillo, Columbella, Regalis.

For market: Sevillano, Mission, Picholine, Manzanillo, Gordal.

EXPERIMENTS IN PICKLING GREEN OLIVES.

At the suggestion of Mr. H. H. Moore, of Stockton, a series of experiments was undertaken with the object of determining the best method of pickling green olives. Green olives can be, and have been, pickled in California by exactly the same methods used for ripe olives, and when treated in this way leave nothing to be desired as regards flavor and keeping qualities. They have, however, the defect, fatal commercially, of losing their bright green color during the process of pickling, or shortly afterward. Practieally all the unripe olives prepared in California turn an unsightly brown or gray, and have for this reason been unmarketable in competition with the imported Spanish olives, which usually retain their bright green or yellowish-green color, even when taken from the brine and exposed to the air for a considerable time on the counters of the grocers. In spite of the opinions of connoisseurs and of the analyses of chemists, which show that the ripe pickled olives are not only more pleasing to the cultivated palate but more digestible and nutritious, the fact remains that the favorite olives with the average consumer, and those for which the trade can afford to pay the highest price, are the large green "Queen" olives of Spain. These are the product of several large-fruited varieties pickled when green by processes which are trade secrets of the Spanish producers, or which having been devised for local conditions are inapplicable here. The finest and largest are made from a variety called Sevillano; though other large kinds are used, and doubtless any large olive such as Macrocarpa, True Picholine, Santa Catarina, and Ascolano, could be successfully marketed, if cured in the same way. Now that these varieties are beginning to be produced in California in notable quantities, it is important that some way of preparing them should be found that will enable them to hold their own against their imported rivals.

The olives used in the experiments detailed below were of the Agostino variety, and were kindly furnished by Mr. Moore from his orchard near Lodi, in San Joaquin County. They were shipped to Berkeley in ordinary wooden boxes, but arrived in good condition, for being hard and unripe they were not at all bruised. The greater part of them were quite green, but a few, 15% or 20%, had commenced to show indications of ripening in a tint of red on one side. Before using, they were divided into two lots of different sizes by means of an improvised grader consisting of a galvanized wire-netting screen.

As it had already been demonstrated that the best results with ripe olives, both as regards color, flavor, and keeping qualities, were to be obtained with weak lye-solutions applied several times, instead of a single treatment with a stronger solution, a first series of experiments was undertaken to demonstrate the effect of these two methods upon green olives. For this series nine earthenware jars of three gallons capacity were taken and filled with the olives to be experimented on. The jars had flat earthenware tops that were supported by a rim on the inside of the slightly constricted necks of the jars, so that when the various solutions were poured in and the jars filled, the weight of the tops kept all of the olives submerged. This complete submersion of all the olives is very important in obtaining uniform color. Each of the nine jars represented a different experiment, as follows:

Experiment No. 1. An attempt was made in this experiment to extract the bitterness without the use of lye. Three gallons of the large olives were placed in a jar and kept in a constantly running stream of water. The water entered at the bottom of the jar, flowed through the mass, and emerged at the top. At the end of six days the color was completely spoiled. The olives had become of a dirty brown, and had completely lost all their greenness, while the bitterness had hardly diminished at all.

Experiment No. 2. This was a duplicate of Experiment No. 1, with the exception that small olives were used. The result was identical.

These experiments showed among other things that a slowly-moving, constant stream of water is much more favorable to the growth of the bacterial and fungous slime which is so troublesome in pickling, than standing water that is removed even so seldom as once a day. The amount of slime produced in the six days of the experiment was sufficient to have spoiled the flavor of the pickles permanently, even had the color not been changed.

Experiment No. 3. Three gallons of large olives were placed in a ½% solution of lye for twenty-four hours. The lye was then replaced with water which was changed every twelve hours. At the end of three days, the olives being still bitter, they were placed in a new lye-solution of the same strength for twenty-four hours. As the bitterness failed to disappear this lye-treatment was repeated at 6, 10, 13, and 16 days, being prolonged for only twelve hours, however, in these cases. Even with these repeated lye-treatments the bitterness had not all disappeared on the fifteenth day, and by that time the color was becoming brownish. On the twentieth day the bitterness had disappeared, but the color was spoiled.

Experiment No. 4. Three gallons of small olives were placed in a ½% lye-solution for twenty-four hours; the lye then replaced with water, which was changed twice a day. In thirteen days the olives had commenced to turn brown and were still very bitter. At sixteen days they were placed in a 1½% lye-solution for twelve hours, and at eighteen days nearly all the bitterness had disappeared, but the color was completely spoiled.

Experiment No. 5. Three gallons of small olives were placed in a 1% lye-solution for eighteen hours, and the water changed twice a day thereafter. At fourteen days the color was still good, but the bitterness had not disappeared, so another 1% lye-solution was poured on and left for twelve hours. This was repeated at seventeen days, and at eighteen days the bitterness was gone, but the color was spoiled.

Experiment No. 6. Three gallons of small olives were treated with a 1½% lye-solution for eighteen hours, and then placed in water changed twice a day. The color commenced to change in four days, and in eleven days was quite spoiled and the bitterness still strong.

Experiment No. 7. Three gallons of large olives were treated for eight hours with a 1½% lye-solution and then with two daily changes of water. The second day another eight-hour immersion in a lye-solution of the same strength was given. In four days the color was quite spoiled and the bitterness still persisted.

Experiment No. 8. Three gallons of small olives were placed in a solution containing 1½% lye and 1½% salt, which was replaced with water at the end of eighteen hours. The water was changed twice a day, but at the end of three days the color was completely spoiled.

Experiment No. 9. Three gallons of small olives were treated for four hours with a 2% lye-solution, and then placed in water changed twice a day. At the end of the second day the color had commenced to change, and at the end of three days it was completely spoiled.

These experiments showed that none of the usual methods of treating ripe olives, viz: short treatment with comparatively strong lye, long or repeated treatments with weak lye, or treatment with water alone, were successful in preserving the green color of unripe olives under the conditions of these experiments. By reference to the following table it will be seen that the green color was destroyed the more rapidly the stronger the lye-solution in which they were placed. In the jars where no lye was used the time of the destruction of the color was intermediate between that of the strong and that of the weak lye-solutions.

Nature of treatment.	Time of turning brown.
No lye—running water	6 days.
Lye ½%, repeated at intervals 4 times	20 "
Lye ½%, and after 16 days 1½%	18 "
Lye 1%, and after 14 days 1% again	18 "
Lye 1½%	11 "
Lye 1½%, and after 2 days 1½% again	4 "
Lye 1½% and salt 1½%	3 "
Lye 2%	3 "

In considering the experiments with lye in this table it would seem that the lye was the cause of the destruction of the green color; but the destruction of the color in those experiments where no lye was used indicated that this was not a full explanation. A jar of untreated olives was left in water accidentally for several days without changing, and it was noted that these retained their green color longer than the olives left in a running stream of water. This suggested that the turning brown was due to oxidation caused by the air dissolved in the running water and in the water replaced daily in the lye-treated olives; and that this oxidation was simply accelerated by the softening action of the lye upon the tissues of the fruit. Another series of experiments was therefore undertaken to see whether it was possible to preserve the green color by extracting the bitterness with a minimum exposure to the oxygen of the air or of that dissolved in water. This series was made with another lot of the same olives used in the first series. Lye-solutions of various strengths were used, and the olives kept in them until all the bitterness was removed. With the weaker solutions it was necessary to renew the solutions several times in order to completely neutralize the acrid substances to which the bitterness is due. All the lye-solutions were boiled before using, in order to expel all the dissolved air; earthenware covers were submerged in the brine.

SECOND SERIES OF EXPERIMENTS.

Experiment No. 1, with ¼ % lye-solution:

Nov. 3,	9:45 P. M.	Placed in lye-solution.
" 4,	9:45 A. M.	Olives and solution unchanged in color.
" 4,	4:30 P. M.	Lye not neutralized, uncolored.
" 5,	11:30 A. M.	Lye nearly neutralized, uncolored.

Nov. 6, 11:30 A. M. Renewed lye-solution; olives green, but bitter.
" 8, 9:00 A. M. Renewed lye-solution; olives green, but bitter.
" 10, 8:30 A. M. Renewed lye-solution; olives green, but bitter.
" 12, 10:30 A. M. Renewed lye-solution; olives green, but bitter; lye straw-colored.
" 15. Olives still slightly bitter; put in 1% salt brine.
" 16. Olives still slightly bitter.
" 17. Put in 2% salt-solution; bitterness almost gone.
" 18. Put in 4% salt-solution.
" 20. Put in 6% salt-solution; olives turned a little brown.
" 22. Put in 12% salt-solution.

Experiment No. 2, with ½ % lye-solution:

Nov. 3, 9:45 A. M. Placed the olives in a ½% lye-solution.
" 4, 9:45 A. M. Lye and olives unchanged in color.
" 5, 11:30 A. M. Lye pale straw color; not neutralized.
" 8, 9:00 A. M. Olives still of good color, but bitter; lye neutralized; solution renewed.
" 10. Lye neutralized; renewed solution; color of olives darkening.
" 15. Put in 2% salt-solution; bitterness almost gone.
" 17. Put in 4% salt-solution.
" 20. Put in 6% salt-solution; olives a little brown.
" 22. Put in 12% salt-solution; olives a little browner.

Experiment No. 3, with ¾ % lye-solution:

Nov. 3, 9:45 P. M. Placed the olives in a ¾ % lye-solution.
" 4, 9:45 A. M. Lye faintly yellow; olives unchanged.
" 6, 5:00 P. M. Lye neutralized; solution renewed; olives still bitter.
" 8, 9:30 A. M. Lye neutralized; solution renewed; olives still bitter.
" 9. Put in 2% salt-solution; bitterness disappeared.
" 12. Put in 4% salt-solution.
" 15. Put in 6% salt-solution.
" 20. Put in 8% salt-solution.
" 22. Put in 12% salt-solution.

Experiment No. 4, with 1 % lye-solution:

Nov. 3, 9:45 P. M. Placed the olives in a 1% lye-solution.
" 4, 9:45 A. M. Lye yellow; olives unchanged.
" 6, 11:30 A. M. Lye not neutralized; olives still bitter.
" 6, 5:00 P. M. Put in 2% salt-solution; lye neutralized; olives still a little bitter.
" 7. Salt-solution colorless.
" 8. Put in 4% salt-solution.
" 12. Put in 6% salt-solution.
" 15. Put in 8% salt-solution.
" 20. Put in 12% salt-solution.

Experiment No. 5, with 1½ % lye-solution:

Nov. 3, 9:45 P. M. Placed the olives in a 1½% lye-solution.
" 4, 9:45 A. M. Lye yellow; olives unchanged in color.
" 6, 11:30 A. M. Lye not neutralized; bitterness gone; color still good.
" 6, 11:30 A. M. Put in 2% salt-solution.
" 8. Put in 4% salt-solution; salt-solution colorless.
" 12. Put in 6% salt-solution.
" 15. Put in 8% salt-solution.
" 20. Put in 12% salt-solution.

Experiment No. 6, with 2% lye-solution:

Nov. 3, 9:45 P. M. Placed the olives in a 2% lye-solution.
" 4, 9:45 A. M. Lye brownish-yellow; olives unchanged in color.
" 5, 11:30 A. M. No discoloration of the olives.
" 6, 11:30 A. M. Lye not neutralized; bitterness gone; olives of good color and like those of Experiment No. 5, except that they were a little soft.
" 6. Put in a 2% salt-solution.
" 7. Put in a 4% salt-solution; salt-solution yellow.
" 9. Put in a 6% salt-solution.
" 12. Put in an 8% salt-solution.
" 15. Put in a 12% salt-solution.

Experiment No. 7:

A duplicate of Experiment No. 6, except that after placing in the 12% salt-solution the pickles were put into a glass vessel, sealed up and heated to 99° C. (210° Fahr.).

The pickles from each experiment were placed in bottles as soon as they were in a 12% salt brine. At this time they were all of good flavor. Those of Experiments Nos. 1 and 2 (¼% and ½% lye) were slightly brown, but the color of the others was excellent. Those of Experiments Nos. 6 and 7 (2% lye) were slightly softened, and their flavor was perhaps not quite so good as that of those treated with weaker solutions of lye. All the pickles remained in bottles of clear glass exposed to the light for ten months, when they were examined with the following results:

After ten months.—Experiment No. 1. The olives were of very good flavor and texture and had kept perfectly, but were brownish in color, and the brine in which they had been kept was also dark brown.

Experiment No. 2. The olives were indistinguishable from those of Experiment No. 1, but the brine, though brown, was less dark-colored.

Experiment No. 3. The olives were of a golden-yellow color and equal to those of Experiments Nos. 1 and 2 in flavor and texture. Half of the brine had leaked out of the bottle, but the olives in the air above the brine had not suffered at all, and were equal in color and flavor to those still immersed. The brine was brownish.

Experiment No. 4. The olives of this lot resembled those of Experiment No. 3, but were a little greener and brighter n color. The brine was a dark straw color.

Experiment No. 5. The olives of this lot were still greener than those of the foregoing experiment, and showed but little of the yellow color. They were about of the color of the imported "Queen" olives. The brine was colored only faintly yellow.

Experiment No. 6. The olives had kept perfectly their bright green color, and the brine was clear and almost colorless.

Experiment No. 7. The olives had the yellowish-green color of those of Experiment No. 5, but the brine was dark-colored, even darker than that of Experiment No. 1. The olives, both of this experiment and of the preceding, had become quite firm and had kept just as well as any, but the flavor was not quite equal to that of those pickled with the use of weaker lye-solutions.

Two months later the pickles were examined again, with results identical with those given above. Those of Experiment No. 3 which were exposed to the air had not suffered at all. The brightest green was that of Experiment No. 6, but the color that would be most acceptable to the trade would probably be that of Experiments Nos. 5 and 7. The objection to No. 7 would be the dark color of the brine. The slight yellowish tint of the brine of Experiment No. 5 would probably not be a serious objection, and the flavor of the olives was distinctly superior to that of Experiments Nos. 6 and 7. Supplementary experiments made later showed that when too strong a lye-solution was used the olives were somewhat bleached, and instead of the bright green of Experiment No. 6 or the yellowish-green of Experiment No. 5, we obtain a pale whitish-green, which is undesirable.

CONCLUSIONS.

This series of experiments shows that it is possible to produce green pickled olives which will retain their color for at least twelve months by the lye-and-salt method of treatment, if properly modified and controlled. The color is preserved, so that exposure to the air *after* the completion of the pickling process does not seriously affect the color for some time. (See Experiment No. 3.) The following process, based upon these experiments, is recommended:

Choice of Fruit.—Only large-fruited varieties should be used, as the small green pickles bring a very inferior price. The olives should be gathered as soon as they have reached full size and before they have colored notably. A slight pink color on one side does little harm, as it disappears during the process, but olives which have reached the stage of ripeness indicated by this first change of color will probably have less of the bright green than if gathered earlier. No two varieties should be pickled together, and the olives should be graded into three or four sizes. The reason for this is that different varieties and different sizes are almost sure to require different strengths of lye-solution, and it is therefore impossible to attain the best results unless this selection is made. The proper strength of lye-solution to use in each case is best determined by a preliminary trial, as follows:

Preliminary Trial.—Take a series—about six—of pint preserving-jars and fill them with the olives to be tested. Pour into them, respectively, a ½%, 1%, 1½%, 2%, 2½%, and 3% lye-solution, sufficient to completely cover the fruit. At the end of forty-eight hours examine them. (It has been found that a sufficiently strong lye-solution will extract the acid and bitter principles of even very bitter olives in forty-eight hours.) At the end of this time some of the weaker lye-solutions will be found to have been neutralized, that is to say all the lye will have been used up in acting upon the acids of the fruit. This will be made evident by the lack of the slimy feeling which the fingers have when dipped into a lye-solution and rubbed together. Suppose that the ½%, 1%, and 1½% solutions are neutralized, and that the 2% still has a slight slimy feeling. This will show that a 2% solution is a little stronger than is necessary to neutralize all the bitter or acrid matters in the sample tested. If, now, we use a 2% solution in curing the bulk of the olives from which the sample was taken, we are able to preserve the green color perfectly. If we use a somewhat stronger solution, say a 2½%, the color will bleach out a little; while if we use a much weaker solution, say a 1%, the green will change to that disagreeable gray or brown which we wish to avoid.

Process.—The appropriate strength of lye-solution having been determined, the olives are placed in convenient receptacles, where they can be treated with a minimum exposure to light and air. For this purpose fifty-gallon barrels with very large bungholes (four or five inches in diameter) and spigots are useful. After filling the barrels with olives the lye of the strength determined in the preliminary trial is poured in. Each barrel should be quite full of olives, and sufficient lye-solution should be put in to come flush with the bunghole. At the end of forty-eight hours the lye should be drawn off, the olives quickly washed with two changes of fresh water, and the barrels filled immediately with a 2% salt-solution. This brine should be replaced successively with a 4% and 8%, and finally a 12% solution, in the last of which the pickles remain permanently. The successive brines should be allowed to act for from forty-eight to seventy-two hours each, according to the size of the olives; the larger sizes requiring more time for the brine to penetrate and to displace the excess of lye which remains. The whole process will thus take from ten to fourteen days.

Absence of Air.—The essential part of the process is to avoid exposing the olives to the air during the pickling, until all the bitterness and acid are completely neutralized by the lye. After this the green color seems to be fixed, and exposure to the air does not change it much, though it is well, all through the process, to avoid leaving the olives uncovered by liquid any longer than necessary.

As different varieties of olives and even the same variety in different seasons and from different localities differ very much in bitterness, the importance of treating each variety separately is evident, as each will require lye-solutions of different strength to neutralize them. Very bitter olives, such as Mission, Sevillano, Manzanillo, and True Picholine, require solutions containing from 1½% to 2½% of pure potash lye, while olives containing little bitterness, such as Ascolano and Columbella, require only from ½% to 1% solutions. As many of the commercial lyes are far from pure, some containing not more than 50% of potash, the number of preliminary tests must usually be at least six, as indicated above. Preliminary tests conducted as described do not require an analysis of the lye, though it is probable that lyes containing a large amount of common salt would act more slowly; and with such lyes a treatment exceeding forty-eight hours might be necessary.

To facilitate the preparation of the different strengths of solutions, it is convenient to remember that as a gallon of water weighs 128 ounces, one and a quarter ounce of solid lye is equal (in round numbers) to one per cent; or that one pound of such lye will make nearly twelve and a half gallons of one per cent solution.

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E. W. HILGARD, Director.

CITRUS FRUIT CULTURE.

By J. W. MILLS.

A CITRUS FRUIT REGION IN SOUTHERN CALIFORNIA.

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PREFATORY NOTE.

By CHARLES H. SHINN, Inspector of Stations.

The University of California Experiment Station has been testing citrus fruits for many years, beginning at the Central station (where soil and climate are very ill-adapted to these fruits) and continuing at the substations as fast as they were established. The results of this work, to some extent printed in annual reports, have been mainly obtained, as was to be expected, in Southern California, the best substation for this work being situated there, in the Chino Valley. At other substations, however, some useful results have been reached, which may be briefly stated.

At the Sierra Foothill substation, Amador County, three varieties of oranges—Konah, Malta Blood, and Washington Navel—on sweet-stock, were planted in 1888. Florida sour-stock seedlings were put in later; then some hardy Japanese stocks (*Citrus trifoliata*). The soil where the first planting was done was poor and rocky, and the trees were several times badly frosted, so that by 1896 this trial was considered a failure, only the Japanese long-fruited "Cumquat," or gooseberry orange, and the dwarf Oonshiu (both on *trifoliata* stock) having succeeded. These, however, have done so well that their culture is strongly recommended for gardens at this elevation (about 2,000 feet) in the Sierra foothills. For standards the sour-stock appeared to be decidedly hardier, and in every way better than the sweet-stock. A new and more sheltered location was chosen on better soil, and here a small orange grove has been established, with every prospect of success.

Oranges were also planted at the San Joaquin Valley substation, near Tulare, and at the Southern Coast Range substation, near Paso Robles. At the latter point they utterly failed, both soil and climate proving totally unsuitable for semi-tropic trees; this fact was therefore published, and no further experiments made. At the former point, Tulare, some of the orange trees have grown, though often heavily cut back by frost. The sour-stock proves most resistant to alkali, and as a rule hardier. The dwarf deciduous orange of Japan (*Citrus trifoliata*) grows and fruits in even stronger alkali, and therefore is recommended as a stock for gardeners in such localities.

The planting of citrus fruits at the Southern California substation began in the spring of 1891, when the foreman set out eight varieties of orange, then three years from bud, on sour-stock, and eight varieties on sweet-stock; also three varieties of citron and three of lemon, all on sweet-orange stock. The tract was well situated, though far from the hills, and on lower ground than the best conditions require. Additions were made to the orchard each following year, and by 1896 about twenty-five varieties of citrus fruits were in bearing. At the present time, the orchard includes every variety of promise which can be obtained in California or from the Department of Agriculture at Washington, besides local seedlings under trial. Some kinds have been discarded and trees regrafted. The orchard is well kept, healthy, and free from insect pests; it constitutes a good working model for an orange grove under valley conditions. A part of the illustrations which accompany this bulletin are from this orchard.

But the culture of citrus fruits has become the leading industry of many districts of California, and it is being developed with surprising skill and energy by very capable horticulturists, some of whom have been almost a lifetime in this occupation. It is therefore essential to the truthfulness of any inquiry into the present problems of citrus-fruit culture that a wider range of observation than that afforded by the substation tract of thirty acres should be taken. Mr. J. W. Mills, foreman of this substation since 1893, was therefore sent out to visit some of the best orchards in leading orange districts of Los Angeles, San Bernardino, and Riverside counties, and to compare the station experience with that of successful commercial growers. The results should possess interest for those who wish to plant citrus fruits in any part of California, since the conditions of soil and climate at Cloverdale, Calistoga, Palermo, Porterville, and other northern and central orange-growing points, while in some respects quite different from those of the southern orange-growing counties, are sufficiently similar to make careful observations in any part of California valuable. Much more complete studies of local conditions have been made in the southern citrus districts than in other parts of the State, and some of the conclusions herein reached may need modification as respects northern districts when an equal amount of local experience shall have been there accumulated.

In citrus fruit districts the high price of land that is known to be well situated, of the best quality, and supplied with water, leads men to extend citrus culture far beyond its natural limits, upon unsuitable soils and into frosty localities. The marked recent advance in average prices of citrus fruits and of well-planted orchards has also caused hasty and careless planting, even in well-established districts. Many old trees are bearing less satisfactory crops than heretofore, and various plant diseases add to the anxiety of the orchardists. Technical knowledge and a high degree of horticultural skill are every year more essential to the prosperity of each individual orange-grower.

The observations of many successful citrus-fruit orchardists have been placed at the service of the station in preparing this bulletin, partly in obtaining the history of the older groves and of the origin of some new varieties, partly in securing needful details respecting more recent practice in planting and culture on a commercial scale, in representative districts. Credit has been given in all cases for such assistance, without which this bulletin would have been merely a record of experiments in one orchard. The discussion is almost wholly devoted to problems of orange culture, but some references are made to the lemon.

The following pages have been condensed and edited from the manuscript furnished by Mr. J. W. Mills, foreman of the substation. All the illustrations are from photographs taken by Mr. Mills.

CITRUS FRUIT CULTURE.

Varieties, Stock, Planting From Nursery, Re-budding Old Orchards, Cultivation, Irrigation, Diseases, Remedies, and Other Practical Problems.

By J. W. MILLS.

VARIETIES OF ORANGES.

The *Washington Navel*, which is so well known that it hardly needs especial description, is still the only orange that the market demands in large quantities. There are, however, several sub-varieties of the fruit, none of which, so far as tested commercially, surpass the best of the original type. The quality of this orange varies according to soil and location. Its fortunate tendency to sport gives promise of ultimate improvement over the original type, and several new varieties of Navel oranges have been selected and are being introduced.

Thompson's Improved Navel.—The first important variation from the Navel was "Thompson's Improved," introduced by Mr. A. C. Thompson, of Duarte, Los Angeles County. The introducer claims that this variety is not a sport, but is a special creation of his own, accomplished by the division and union of buds of select Navel, St. Michael, and Blood oranges. (See Mr. Thompson's note on his Navelencia orange, page 7.) The practical difficulties in such division and union are so great that many more experiments along this line are necessary to confirm or disprove Mr. Thompson's claim of the origin of this variety. It is a beautiful fruit, which has been eagerly sought after and widely planted. There are conflicting opinions as to its value as a shipping variety in different sections of the southern citrus belt. Mr. C. C. Buffington, of Corona, an extensive buyer and shipper of citrus fruits, says: "There has always been a doubt in my mind as to its being a practical variety, owing to its thin skin and tender pulp."

Mr. H. D. Briggs, of Azusa, writes: "My five years' experience is that I consider the Thompson superior to the Washington Navel, for the following reasons: It has a smoother skin; it has a thinner skin; it is higher colored; it is a heavier bearer at the same age; the tree is a little larger and more upright at the same age; it stands shipping fully as well. The only fault I have to find with it is that it dropped far heavier last spring, but still the trees have twice the number of oranges left that the Washington Navels of the same age have. The soil is a rich, sandy loam that is predisposed to grow a large, rather coarse Washington Navel."

The fruit of the Thompson's Improved Navel as grown at the Pomona substation does not seem equal to the best type of Washington Navel. This may be due to its thinner skin, which is more injured by the frost. A temperature of 25° Fahr. is almost sure to be reached some time before the fruit is fully ripe, and this will usually injure a thin-skinned early or mid-season orange where a thick-skinned one would be but slightly injured. The Thompson's Improved, therefore, is not recommended for planting in locations that are frequently subject to severe frost.

The thin skin of Thompson's Improved Navel does not necessarily detract from its shipping qualities, but there may be other qualities that make it a poor shipper, such as a loose attachment of the divisions of the fruit. The St. Michael Paper-Rind has a much thinner skin and is an excellent shipper.

Golden Nugget Navel.—This sub-variety is a new, early kind that was found to be sweet and juicy on the 20th of November, at Glendora, Los Angeles County. There is but one tree of full-bearing age, and it is in a favorable locality for early ripening. Mr. J. P. Englehardt, of Glendora, in whose orchard it stands, writes as follows: "The tree was purchased among a lot of nursery stock at Alhambra, ten years ago. It looked like all the rest, but it would not grow, and was stunted in the first place. I cut it back to almost nothing, when it put forth leaves of a different appearance, and subsequently bore fruit that differed from the others."

Mr. R. M. Teague, of San Dimas, who is propagating this variety, says: "This orange ripens very early in the season, and is a very thin-skinned, nice-appearing fruit. There being only one tree in fruit, it is hard to state just what the average time of ripening will be; all we can say is that it is very early."

Golden Buckeye Navel.—This sub-variety is reported to be a sport from the Washington Navel. The rind is as thin as that of the Tangerine, but, unlike the latter, it adheres so closely to the pericarp that the divisions can be plainly seen through it after the fruit has been picked a few days, giving it the appearance of a nutmeg melon. Upon inquiry, Mr. Teague, of San Dimas, writes: "The orange tree you mention as growing in Pomona originally came from here; there happened to be one branch that 'sported' to this in the twenty-acre grove here at San Dimas. These oranges ripen very early, are very thin-skinned, with a slight pineapple flavor, and all pack as 'fancies.' The only objection to this orange is the color of its skin, which is a pale yellow, and so it seems to be a cross between a Washington Navel and a St. Michael."

Navelencia.—This orange is a recent introduction of Mr. A. C. Thompson, of Duarte, the originator of Thompson's Improved. Some growers say that trees of the Navelencia grown by them compare favorably in size, when three years old, with five-year-old Thompson's Improved, when both are grown under the same conditions. The Navelencia tree is a more upright grower than the original Washington Navel. When Thompson's Improved is sweet enough to be pleasant to eat, Navelencia is still unfit to eat. While its lateness and other desirable qualities will probably give it a place with citrus-growers, it is not likely that it will hang on the tree and retain its good qualities as long as the true Valencia.*

Valencia Late.—The Valencia orange ripens during May and June, and commercially stands next to the Washington Navel. It will, perhaps, never be shipped as extensively, because it comes in at the end of the orange season when early deciduous fruits are in market. But this variety has the additional advantage of keeping well when left all summer on the tree, and can thus be held over for the early winter and holiday trade. Early new varieties will probably, in time, take its place

*Mr. Thompson's account of the origin of this variety is given by himself as follows: "The Navelencia is an equal production of one half Valencia and the other half Thompson's Improved Navel orange. In 1890 I made several crosses, but this was the only one that made a complete union. In many cases one of the buds so spliced together would start several days before the other made a move, so both germs grew separate; in some cases one half died, in others both barks would unite, but only one germ would start; this one seemed to grow, both germs uniting, both barks catching quickly, and made one shoot. This operation has to be watched every day with a powerful glass after the fifteenth day from the time the buds are inserted in the young trees in the nursery, to make sure that both germs have united; the half buds must be of equal size and age, and of equal ripeness, and concave on the germ edges to fit the convexity of the tree, when held tightly together. Wax over lightly after pressing them close to the tree, covering the whole cut with wax cloth for fifteen days, then begin examining as to the progress, re-wrapping every time until you are satisfied that the experiment is a success."

for this purpose, as it assumes a greenish color when left on the tree after its natural period of maturity.

In regard to the prospects for future plantings of the Valencia Late, Mr. A. H. Naftzger, president and manager of the Southern California Fruit Exchange, writes as follows: "Since they come at a time when the demand for oranges is, in the nature of things, limited, I doubt if a larger acreage than is now coming forward in California gives good promise of satisfactory results."

Redlands Early Orange.—This is an early seedling found in a nursery row, and now being tested by Mr. H. H. Smith, of Redlands. It ripens for the Thanksgiving trade, at which time it has high color, and is very sweet, but thought by some growers to lack in flavor. Samples exhibited at the Farmers' Club Institute held at Riverside December 20, 1900, were fully matured and more palatable than any other variety shown at that time. The oranges are small, averaging 250 or even more to the box.

Seedlings.—While no one now thinks of planting seedlings, yet some of the best paying groves are composed of these, as the immense size that the trees attain at the age of fifteen or twenty-five years makes them enormously productive. Individual trees in old and well-kept groves have been known to produce forty boxes of oranges in one season. Seedling trees that are planted twenty feet apart, and well cared-for, will become crowded when they are twenty or twenty-five years old. The side branches then make a feeble growth, the trees become tall, and produce fruit chiefly on the upper part. Under such circumstances the expense of gathering is increased and there is a greater proportion of poor fruit. The trees should be pruned so as to admit more light to the lower branches, which is sometimes done by shortening-in the side limbs and heading-back. But a better way is to bud-over, and remove the tops of every other tree, so that the new tops will alternate with the tall seedling trees both ways in every row. Seedlings sixteen years old, when budded have each produced eight boxes of fine Washington Navels during the next four years, while the alternating seedling trees, not budded, produced more fruit per tree and of much better quality than they did before the others were budded. The accompanying photograph (plate 1) shows the splendid growth of a four-year-old Navel orange top on a sixteen-year-old seedling. The tree was beheaded six weeks after budding, and was protected from frost by palm leaves.

Blood Oranges.—Ruby is the earliest of the desirable varieties of blood oranges, and is a prolific bearer. The fruit is rather small at the

Pomona substation, but it has a high color and fine flavor. Malta Blood is larger than the Ruby, but it bears less and is a poorer orange. There is only a light demand for either variety.

Mediterranean Sweet.—This kind was at one time popular, but its tendency to bear small crops in certain sections, even under the best of care, makes it untrustworthy. Numbers of Mediterraneans are being budded-over to Washington Navels.

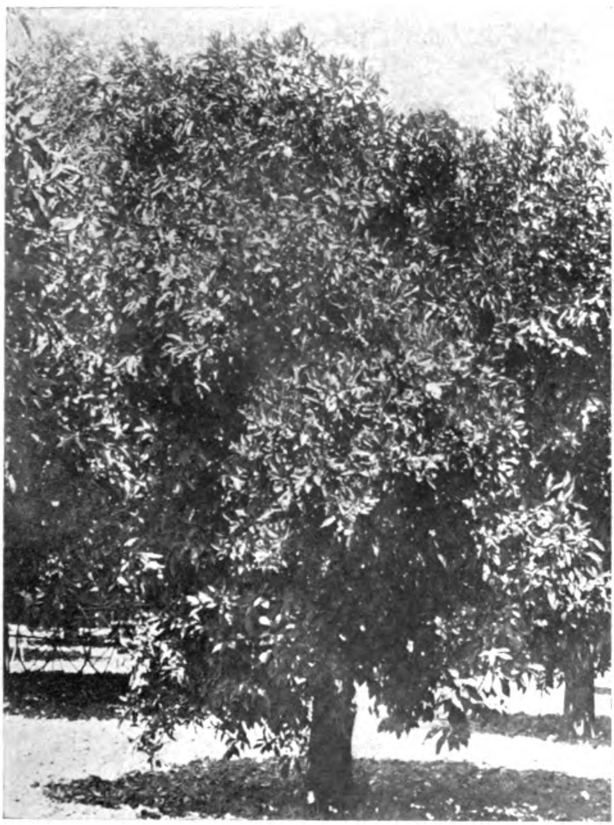


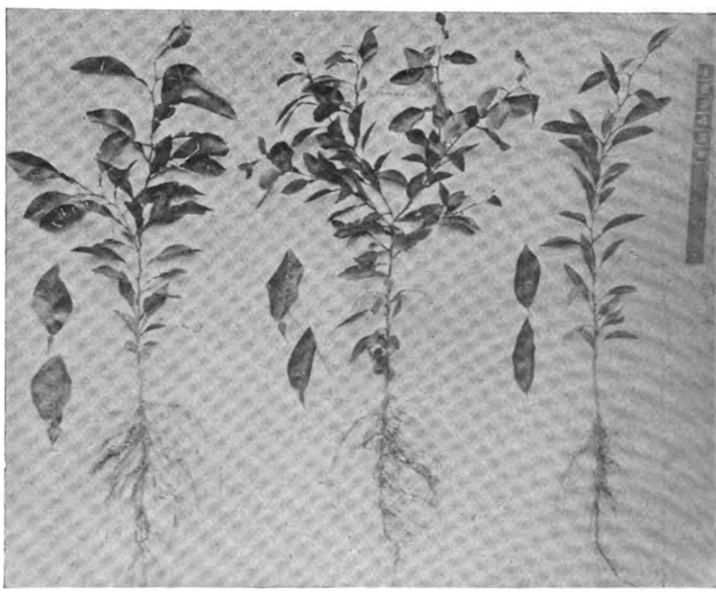
PLATE 1. OLD SEEDLING ORANGE BUDDED TO WASHINGTON NAVEL.
Four-year-old top on sixteen-year-old seedling.

St. Michael Paper-Rind.—This is an old variety, which, though strongly approved by some growers, is not now being planted to any appreciable extent for commercial purposes. It is a small, late variety, with extremely thin rind, and, as it is of high quality, can be recommended for family orchards.

Miscellaneous Varieties.—Many varieties of oranges that have no recognized commercial standing have long been classed as "seedlings" by the trade, and therefore are of lessening importance in citrus-fruit districts. Nevertheless, new varieties from all parts of the world are worth testing, together with promising sorts of local origin, and while very few of them can expect to gain a place in commerce, many will be useful in gardens. The required standards, as shown by citrus fairs, are each year more rigorous. These standards are given at the end of this bulletin.

THE STOCK FOR CITRUS FRUITS.

Little attention has been given in California to the hardiness of different budding-stocks. At a time when some sour-orange stocks



a b c

PLATE 2. ROOT-SYSTEMS OF SEEDLINGS.

a. Florida Sour-Seedling. *b.* Pomelo Seedling. *c.* Common Sweet-Seedling.
All of the same age—18 months.

were imported from Florida, a few trees budded on this root were planted; but the demand for citrus fruit trees rapidly increased, and horticultural quarantine laws came into operation against importation, so that the use of stocks grown from native sweet-seedlings became general. This is still considered "as good as any" by nearly all of our orchardists. Some use pomelo (*Citrus aurantium* var. *Pomelanus*, Willd.), and a few use the native wild orange of Florida (*C. vulgaris* var. *Bigaradia*, Risso).

The root-systems of these three stocks vary considerably, even in the seedling-beds. At the age of eighteen months from the seed there is little difference between the root-systems of the Florida sour and the pomelo (plate 2, *a* and *b*), though the former is better balanced. The sweet-orange seedling (plate 2, *c*) is but moderately well supplied with fibrous roots, which soon develop at the expense of the crooked and irregular tap-root.

Sweet-Stock Root-System.—In a porous soil which has been well watered from the time of planting, the main mass of the root-system of bearing trees on sweet-orange stock concentrates in a horizontal layer about eighteen inches thick, the top of which is eight or ten inches from the surface. This is well illustrated by the accompanying view of the main

PLATE 3. MAIN ROOT-SYSTEM OF A THIRTY-YEAR-OLD SWEET-SEEDLING.

roots of a tree that had grown in a rich, sandy loam for thirty years where artesian water was cheap and abundant and was freely used during the entire life of the tree. (See plate 3.) Two hundred trees that were pulled from the ground in the same orchard showed the same kind of a root-system. Over-irrigation might be thought responsible for this shallow rooting, but ten acres of the same variety that grew for sixteen years in a soil containing more sand and gravel than that just described, where water was always scarce and expensive, had the root-systems distributed in much the same way. (See plate 4.) In the heavy soil of Riverside the same condition prevails. In short, the general experience on all kinds of soils and under different methods of irrigation shows that *it is the nature of the sweet-orange seedling to form a shallow root-system.*

Careful studies of the root-systems of sweet-oranges have been made at the Pomona substation, where the trees have always received deep and thorough irrigation, the water having been allowed to run from forty-eight to seventy-two hours at a time. Deep irrigation was here followed by deep cultivation from the time the trees were planted, and this somewhat discouraged but did not remove the shallow-rooting tendency. The ten-year-old Washington Navel on sweet-seedling stock, illustrated in plate 5, fig. 1, had three of its heaviest lateral roots, starting out six inches below the surface, severed by the plow, at a distance of two feet from the tree and of ten inches below the surface. (*a* in plate 5.) At this point a secondary lateral (*b*) developed, and descended at an angle of about sixty degrees from the perpendicular, until it reached a depth of two feet, when it assumed an almost hori-

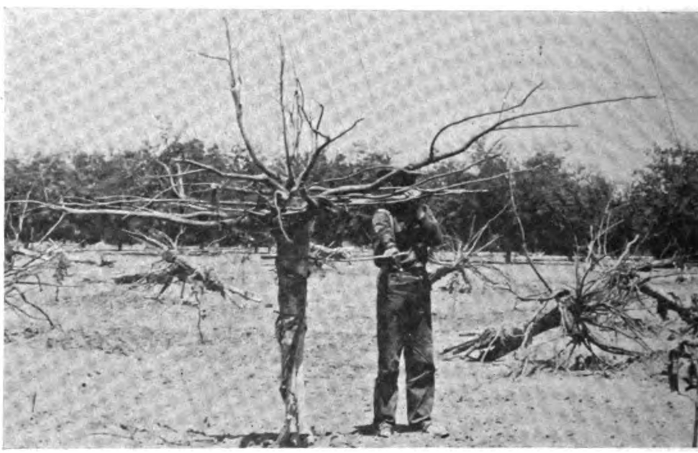


PLATE 4. ROOT AND STEM OF SIXTEEN-YEAR-OLD ORANGE TREE ON LIGHT SANDY SOIL. Has always been short of water.

zontal position. As no fertilizers have ever been applied to the orchard there could have been no influence from that source which would cause the roots to come near the surface. The original tap-root had not penetrated deeper than four feet ten inches (*c* in plate 5). The longest lateral had a total length of fourteen feet, with many turns, at no time going deeper than one foot. From the main laterals were numerous secondary laterals that penetrated from one to two feet, and from these numerous fibrous roots extended through the soil in all directions. To sum this up, *the sweet-orange is a surface-growing stock which has few or no deeply-penetrating roots.*

Advantages of Pomelo Stock.—Nearly all the orange trees now bearing in Southern California are budded on sweet-orange stock, but the pomelo is rapidly taking its place. There is still some prejudice against this as a budding stock, as some growers think it less hardy than the sweet-orange. It makes, however, a very healthy tree, and is said to stand next in value to the sour, or hardy, stock among Florida growers. The seed of the pomelo is easily obtained, and it germinates more quickly than does orange seed. The root-system of a one-year-old pomelo seedling is excellent, but the tap-root is crooked, like that of the sweet-orange. (See plate 5, fig. 2.) Some of the lateral roots of the

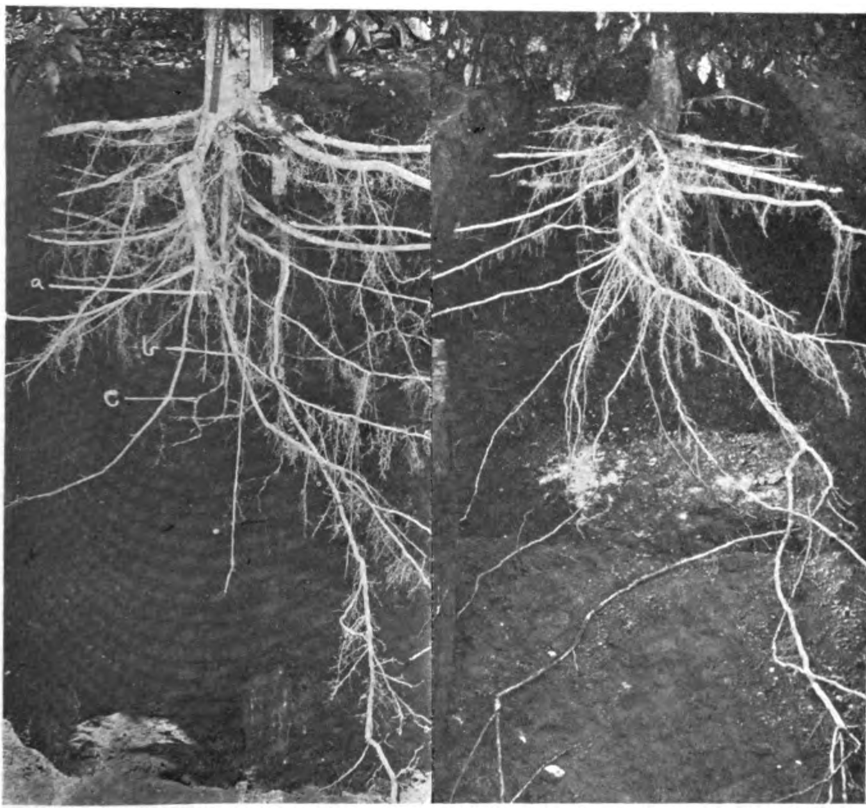


Fig. 1. Fig. 2.

PLATE 5. ROOT-SYSTEMS OF SWEET-ORANGE AND POMELO STOCKS.
FIG. 1. Sweet-orange stock; ten years from time of planting.
FIG. 2. Pomelo stock; seven years old.

pomelo soon develop at the expense of the tap-root, making a prodigious growth. A seven-year-old seedling pomelo, whose root-system was studied at the substation, had a tap-root four feet long, making a healthy though small growth, while the largest lateral root started two feet below the surface and extended for a distance of twenty-six feet, or two feet beyond where the next tree was planted, at an average depth of about eighteen inches below the surface. Over ninety per cent

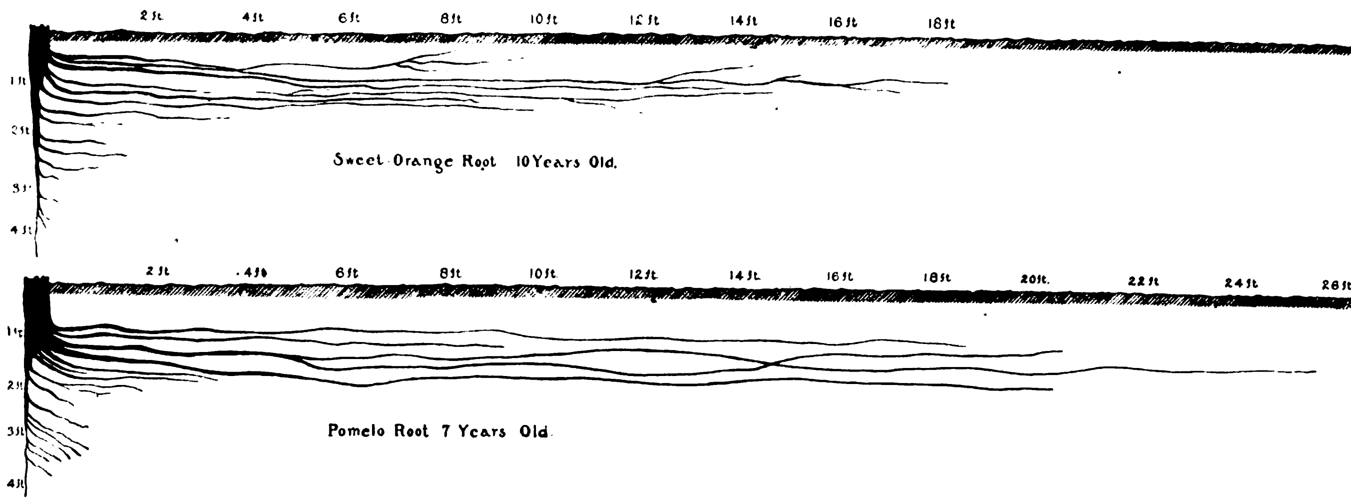


PLATE 6. RELATIVE LENGTH OF LATERALS AND DEPTH OF PENETRATION OF SWEET-ORANGE AND POMELO STOCKS.
Each had deep cultivation and irrigation from time of planting.

of the root-system exposed was found to be confined to a layer between ten inches and two feet below the surface. The accompanying views on plate 5 show the superiority of the pomelo over the sweet-orange in mere root development. The seven-year-old pomelo, figure 2, had proportionately a much larger number of fibrous roots than the ten-year-old sweet-seedling. The pomelo roots ran deeper beneath the surface than the sweet-orange, the majority sinking below fifteen inches. Plates 6 and 8 show drawings of the root-systems of sweet-orange, of pomelo, and of Florida sour stocks, which further illustrate these points.

The Florida Sour-Orange.—The sour-orange stock was introduced into Southern California by Twogood & Cutter, of Riverside, during the early days of citrus planting. It is a very useful budding stock, is called one of the most hardy of the strong-growing citrus fruits, and is used extensively in Florida and Europe in localities where the "foot rot" or "mal di goma" is liable to attack orange trees.

There has been much discussion among orange-growers in California as to the relative merits of sweet- and sour-orange stocks, and even now there seems to be no generally recognized superiority of either. Growers having orchards on sweet-stock claim that it is as good as any, while those having trees budded on sour-stock think the same of them. Disinterested judges have said that they can see no difference where the two stocks have received the best of care. One of the thriftiest Washington Navel groves in the Riverside section is budded on sour-stock, but during its early bearing period this sour-stock grove did not produce as much fruit as did other groves of the same age which were budded on sweet seedlings. In recent years, however, it has been producing abundant crops. On the grounds of the substation Washington Navel trees budded on both varieties of stock have always had the same care, and on an average have produced equally well, when the same stock developed numerous laterals. The deep rooting of a Florida sour-stock at the substation is well illustrated by plate 7, which shows a nine-year-old Washington Navel tree and its sour-stock root-system. The longest and uppermost lateral started six inches below the surface and descended at once at an angle of forty-five degrees until two feet below the surface; then extended in a horizontal position for ten feet from the tree and rose to within eight inches of the surface, when it was cut by the plow. It then grew downward to one foot and horizontal for eight feet more. The longest tap-root was nine and one half feet.

Individual sour-stock roots differ from each other in manner of growth. A number of trees were examined and the numerous tap-roots went deep in every case. Those trees which had few lateral roots made less growth and produced a much smaller amount of fruit than those which had numerous laterals near the surface. The root-systems of

PLATE 7. WASHINGTON NAVEL ON FLORIDA SOUR-STOCK ROOT. NINE YEARS OLD.

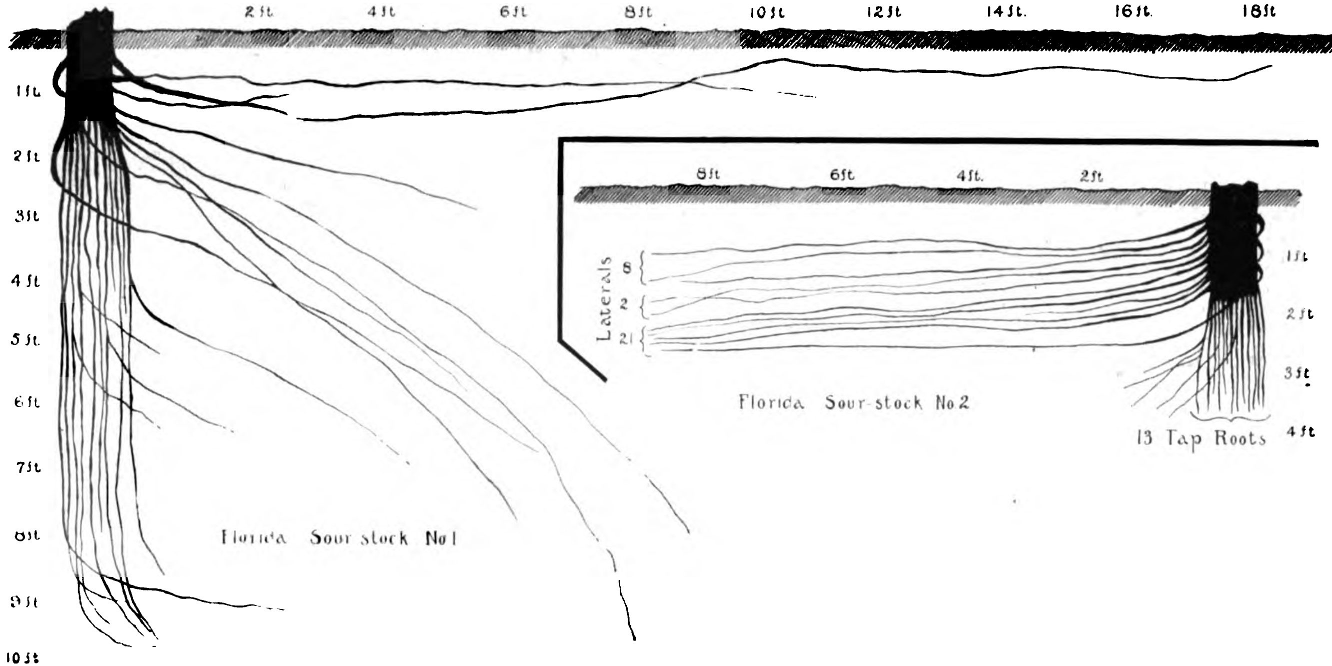


PLATE 8. SHOWING LENGTH OF LATERALS AND DEPTH OF PENETRATION OF FLORIDA SOUR-STOCK.

No. 1. Produced 110 pounds of Navel oranges when 9 years old. Thirteen laterals in half of root; had few fibers.

No. 2. Produced 204 pounds of Navel oranges when 8 years old. Thirty-one laterals in half of root; had many fibers.

two of these Florida sour-stocks at the substation are shown by drawings on plate 8. It is plainly a very strong, healthy, and valuable root-system. The orange tree shown on the left side of the chart bore 110 pounds of oranges when nine years old. The descending roots were traced to nine feet from the surface. The other tree, shown in part at the right side of the chart, bore 204 pounds of oranges when eight years old. The accompanying data shown in the illustration are well worth studying.

There has been some complaint among growers that Navel orange trees budded on sour-stock become more liable to frost than those budded on sweet-seedlings. This is not confirmed by recorded observations. A letter from Grao, Spain, in the United States Consular Reports, says that stocks from the sour-orange raised from seed "are more vigorous, more luxuriant, and of longer duration; besides, they best resist the cold, for which reason they are preferred and chosen for the trunks of trees of tall growth." At the Pomona substation there has not been any noticeable difference in the hardiness of orange trees grown on the two kinds of stock—sweet-orange and Florida sour.

It has been claimed by some growers that sour-stock has an influence on the quality of the orange. Several firms who handle large quantities of all kinds of fruit from both California and Florida were asked if they had discovered any such difference. P. Ruhlman & Co., of New York, wrote under date of July 1, 1901: "We are not able to enlighten you as regards the difference in the eating- and keeping-qualities of oranges grown on sweet- and sour-stock. In our judgment the soil has everything to do with the keeping-quality of oranges. For instance, we have known several orchards whose fruit formerly arrived from Florida in decaying condition, whether it was shipped early or late. Now, by proper fertilizing, and principally the use of potash,* the fruit has changed in character and become of the best keeping-quality (would hold up for a month)."

James S. Watson, president of Porter Bros. & Co., of Chicago, wrote, July 8, 1901: "We consider oranges budded on sour-stock to be of better eating-quality and to have better keeping-qualities than those budded on sweet-stock. That has been our experience, especially in Florida."

The chemical analyses of oranges grown on sweet-stock and on sour-stock, made at Berkeley by the California Experiment Station, and published in previous reports, show such slight variations, easily arising from unavoidable differences in the ripeness of the specimens used, that the theory of the poorer quality of fruit grown on sour-stock can not be justified.

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*The soils of Florida, as shown by many analyses, are very deficient in potash.

Conclusions Respecting Stocks.—The reader, examining with care the quite different root-systems shown in the preceding illustrations, and following the observations heretofore given in this paper, will be prepared to form a trustworthy opinion of his own. He will note that the sweet-orange root is a persistent surface-feeder, having almost its entire root-system above a depth of eighteen inches and rising to within eight inches of the surface. This stock, he will observe, produces an abundance of fibrous roots that concentrate near the surface, just beneath the reach of the plow and cultivator, thus making the tree too susceptible to drought.

On the other hand, the root of the sour-orange penetrates to a depth of nine feet or more (see plates 7 and 8), sometimes having numerous laterals near the surface, and sometimes having fewer but more sharply descending laterals. Both a deep root-system and broadly extending laterals, not too near the surface, are essential to the ideal stock. There would seem to be room for some selection among sour-stocks so as to obtain these qualities in the highest possible degree. Though the sour-stock does not appear to bring trees into full bearing as soon as do the sweet-orange and the pomelo stocks, the value of the sour-stock in other directions may compensate for this defect, and it seems probable that in localities where the sweet-stock fails, sour-stock will be used to a greater extent than now.

It has been shown that the pomelo laterals are found at a somewhat greater depth than the laterals of the sweet-orange. The pomelo produces more fibrous roots than do either of the other stocks, and consequently the tree is a ravenous feeder. It is resistant, to a certain extent, to the form of gum disease that attacks the roots of citrus trees. On the whole, the pomelo is deservedly becoming the favorite stock in Southern California. In practice it has succeeded better at the station than has the sour-stock, which seems to lack uniformity of root growth, sometimes having few laterals, in which case the crops are small. The pomelo seedlings have made the best growth in the nursery.

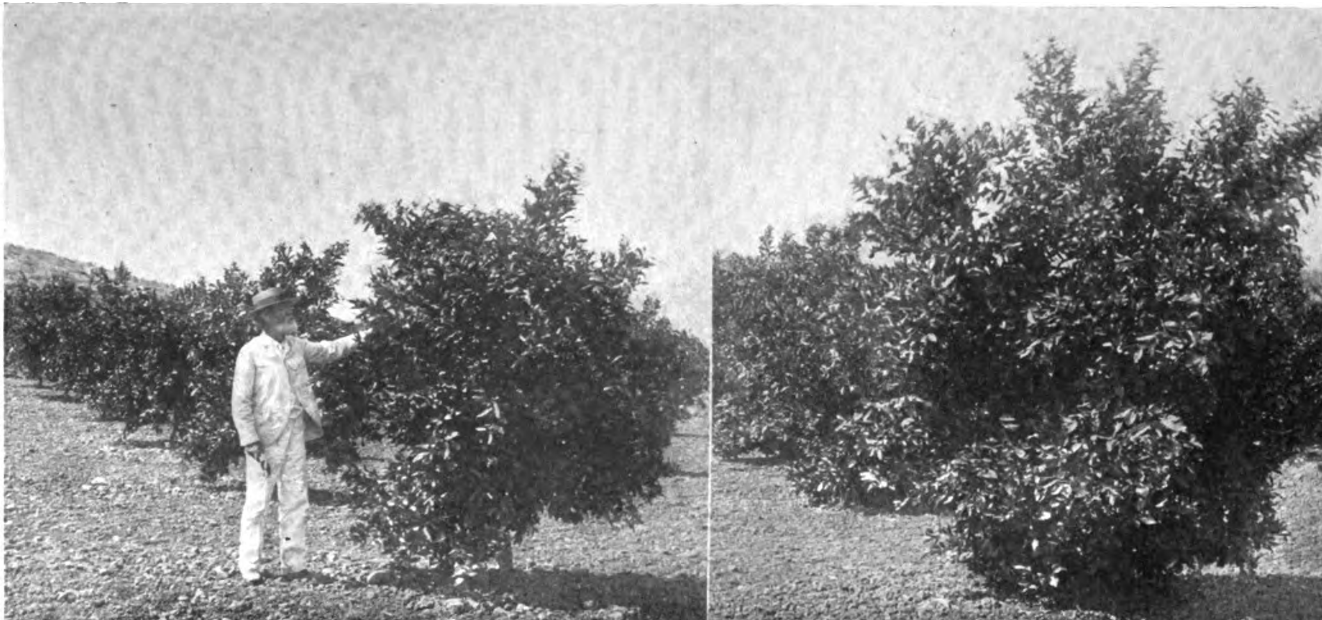
METHODS OF PLANTING ORCHARDS.

The land chosen for the site of an orange grove should be surveyed, and well graded wherever necessary, so that water will flow to every part of the tract from the main pipes or ditches. It ought to be thoroughly worked, at least a foot deep, plowing twice and harrowing well; a subsoiler attachment can be used to loosen the soil several inches below the bottom of the plow-furrows. The orange tree requires a warm, rich, and well-drained soil, which receives the best of cultivation. The water system must be under complete control, so that waste and over-irrigation can be avoided. The soils of the orange sections vary considerably in respect to the percentage of sand, decomposed granite, limestone, or red oxid of iron which is claimed to give high color to the fruit, but all are suited to irrigation and have a porous, well-drained subsoil.

The Ordinary Transplanting Method.—The almost universal method of moving young orange trees from the nursery is to cut off a large part of the top, leaving short stubs of branches, and even from these the leaves are sometimes stripped. This, of course, is to balance the loss of a large part of the root-system at the time of transplanting, and to lessen evaporation. Twenty or thirty gallons of water are usually given to each tree at the time of planting. If the leaves do not fall after the trees have been planted a short time, but show a disposition to turn yellow, they should be removed.

The Reed System of Transplanting.—Much better results are obtained by the method adopted by Mr. J. H. Reed, of Riverside. According to his method, vigorous trees are selected in the nursery, and are well watered before removal. The longer branches are but slightly cut back, leaving most of the foliage on. The trees are then lifted with large balls of earth, and are taken directly to the plantation, where holes two feet deep and two and a half feet wide have been prepared, into which they are placed, and the earth is well filled-in around each ball, not firmed, but settled with water, so that the trees will stand at the same height as they did at the nursery. No planting should be done unless there is irrigation water available at the time. After the ground has been soaked for several feet on all sides of the newly-set trees, thorough cultivation should follow, as soon as the land is in a proper condition. Under any system of transplanting this is good practice.

Mr. Reed says further: "A small amount of fertilizer is applied soon after planting, for the young roots to use when they first start out from the balls. A pure bat guano with a high percentage of nitrogen, about three fourths of a pound to the tree, has been found to give the best results; but any commercial fertilizer rich in nitrogen, or animal fertilizer, if placed properly and kept moist, answers well. It is applied in trenches each side of the ball, at right angles with the irrigation furrows, and reaching to them. They may be made by plowing a deep furrow and deepening with a shovel to ten or twelve inches. The material is carefully distributed and slightly mixed with the earth at the bottom of the furrows; the water from the irrigating furrows keeping this always moist, it is available as soon as reached by the rootlets. This also tends to deep rooting. Thorough irrigation should follow planting every twelve or fifteen days during the first summer. The whole space between the rows should be thoroughly and deeply wet—

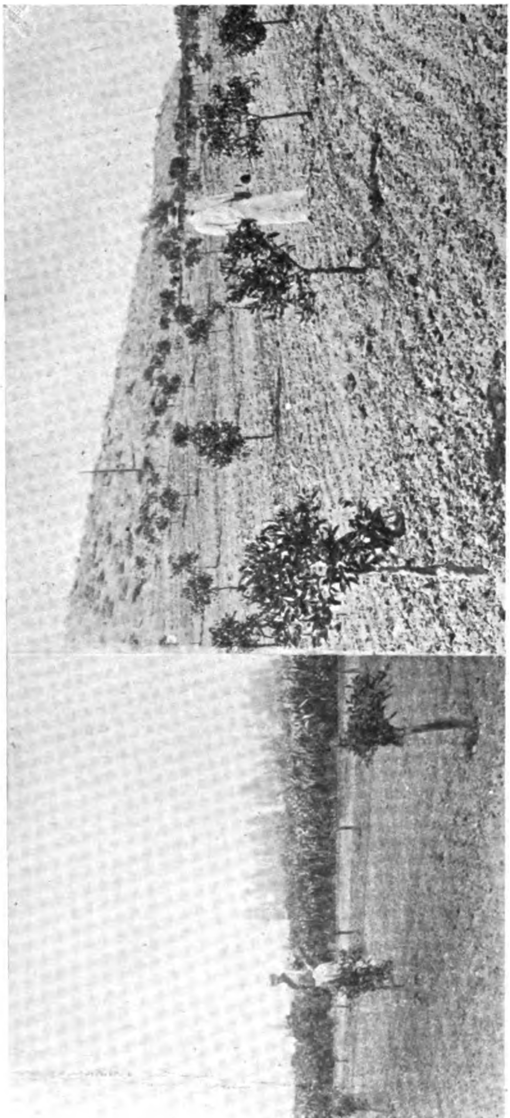


27 months.
Ten boxes of oranges per acre in the second year.

38 months.
One hundred boxes of oranges per acre in the third year.

PLATE 9. WASHINGTON NAVEL ON SWEET-STOCK, ACCORDING TO THE REED METHOD.

not merely a narrow strip on each side of the rows. I have traced roots that have grown during the first summer over six feet from the tree, and these should be well supplied with moisture at all times."



The Reed Method. Trees 40 days after planting; less than one per cent required cutting back.

Ordinary Method. Trees 6 months after planting.

PLATE 10. COMPARATIVE GROWTHS AFTER THE ORDINARY AND THE REED METHODS OF PLANTING.

The advantage claimed for the Reed method is that it retains the top of the tree, and makes use of it immediately. This retention of nearly all the leaves and branches enables trees under proper conditions to produce a much more vigorous growth than under the ordinary system of severe pruning, when moved from the nursery. The best of care is essential to success in this method. If trees are to receive poor or only ordinary treatment after being set in the orchard, the common method of severe pruning is best. Mr. Reed himself prunes back any trees that show lack of vigor after being transplanted, watered, and fertilized.

The good start given to trees by the Reed method is shown in their size, vigor, and productiveness for an indefinite time, and it is also claimed that a crop of oranges is obtained, without injury to the trees, one year earlier than if they were planted by the usual method. Trees thus planted (on the Reed system) produced over one hundred boxes of oranges on ten acres, the second year from planting, and one box per tree three years from the time of planting. The trees are shown in plate 9. Ten acres of trees five years old produced 2,500 boxes. There was no appreciable injury done the young trees on account of the early bearing, for they continued to make a sturdy growth while maturing the crop of fruit. Trees planted in the usual way one year before, on adjoining land that is similar in character, although receiving good care from the start, are not now as large as those of Mr. Reed, though apparently thrifty.

This method of transferring trees to the orchard and securing their rapid establishment there, is based upon intelligent selection in the nursery and very careful attention to details after transplanting. Mr. Reed does not claim that he originated the method, but it has not been observed except in his orchard, which furnishes an excellent illustration of its value under proper conditions. The photographs given on plate 10 show the contrasts between an orchard planted by ordinary cutting-back methods and one planted on the Reed system.

The "Post-hole" Method.—There is another new system of planting orange trees that is being used at the Southern California substation, but practical work has not been carried on long enough to demonstrate its real value. In this method, holes are bored with a post-hole auger in the bottoms of the regular-sized tree-holes, to a depth of five or six feet. They are filled up to the point at which the bottom of the tree rests with peat or well-prepared compost, thus affording good drainage. The roots, it is thought, will follow this rich soil downward, and thus establish a deeper root-system. In selecting a soil for any "post-hole" planting, it is very important to remember that young orange roots are easily injured by alkali or strong fertilizers, and care should be taken to avoid an injurious compost or one that prevents free drainage.

WORKING-OVER OLD ORCHARDS.

In every fruit district, the introduction of inferior varieties necessarily causes much loss to growers, as it is expensive to replant or to work-over old orchards. This is the price that horticulturists willingly pay for new and improved varieties. The orange-growers of Southern California have experimented with almost every known variety, and have been compelled to abandon a number that once were popular. The heaviest loss incurred was because of the inferior Australian Navel which preceded the Washington Navel and sufficiently resembles it in growth to have been sold in numbers of cases for that far better variety.

PLATE 11. WORKING-OVER OLD ORCHARDS. Old Mediterranean Sweet re-budded to Washington Navel. Tops left on during first winter as protection against frost.

In recent years many trees of Australian Navel, Mediterranean Sweet, and seedlings have been re-budded to the Washington Navel and its improved types.

While it is easy to perform the operation of budding, it requires special knowledge and skill to get the new tree-top rightly started and through the first season. Even an old orange tree will take buds in the main branches or trunk, and will produce a luxuriant growth from the buds the first year, if properly managed. But if such trees lose their tops after the first summer's growth, they are usually worthless, or are not profitable for years. In such cases it is better to take out the trees and plant young budded trees from the nursery.

The Method of Re-budding Trees.—Old Mediterranean Sweets are among the most difficult of citrus trees to re-bud, and very poor results will be obtained if they are handled by ordinary methods. Mr. E. L. Koethen and Mr. O. D. Wilheit, of Riverside, have been very successful in budding-over all kinds of old citrus trees, including Mediterranean Sweets. They trim out all branches that are not used to insert buds into, and then thin out the remaining branches above where the buds are inserted. This is done early in the spring, and at the time of budding. The removal of surplus limbs directs the entire flow of sap into the branches containing the buds, which results in their healing-over quickly and becoming well united. Upon the removal of the tops of the trees, the buds start at once. All saw cuts are covered with some material that will exclude the air, usually grafting wax, though Mr. Koethen has experimented with thin putty, and finds it much cheaper, more durable, and not injurious to the tree. After the tops are removed, the trees should be whitewashed to prevent sunburn.

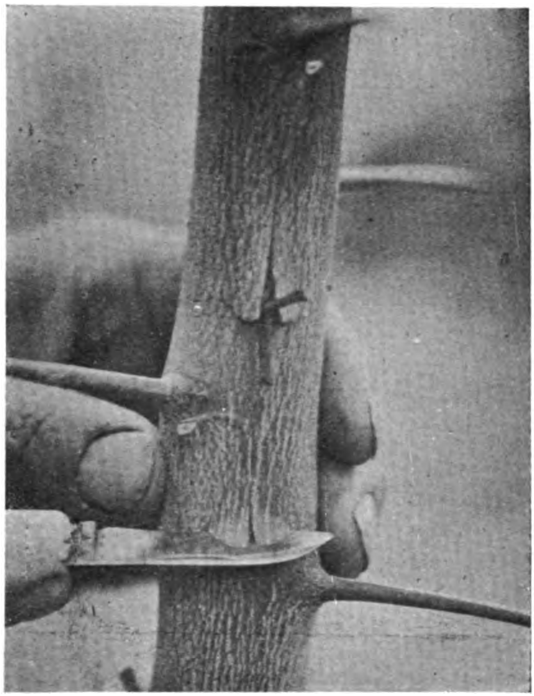
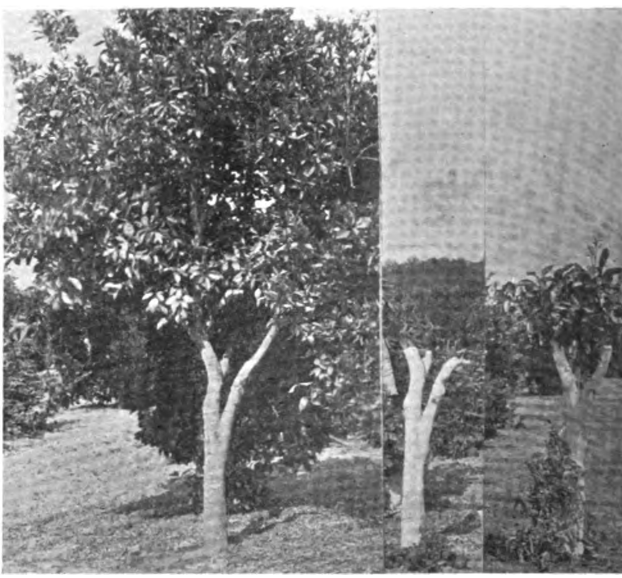


PLATE 12. WORKING-OVER OLD ORCHARDS.
Placing the bud.

Value of "Cured" Buds.—The best success comes from using "cured" buds; these are buds that have been cut from the tree and kept in damp sand or moss for a few weeks before using. When treated in this way they become tougher, and when inserted into a tree that has freely-flowing sap they absorb it more readily. When buds are well cured, and not allowed to become either too wet or too dry, they are not easily injured in handling. The delicate germ is very brittle when the scion is first cut from the tree, and the slightest touch will sometimes destroy it.

Placing the Bud.—The incision which is to receive the bud is made by running the knife down the side of the branch or trunk of the tree. The cross-cut is made at the lower end of the incision instead of at the top, as is the usual method, and slants upward. By giving the knife a slight twist before removing it from the last cut, the two corners are turned out, which, with the upward slant, forms an opening, into which the bud slips easily. Narrow strips of waxed cloth are then wrapped around the limb, completely covering the inserted bud and the incisions. The insertion of the buds from below gives better protection from rain and dew. (See plate 12.)

When to Remove the Bands.—These waxed bands are allowed to remain on the buds for from four to six weeks, according to the weather. During such a season as the spring of 1901, which was cool and damp, citrus trees make very little growth. Under these circumstances the waxed bands should remain a longer time. The bands were removed



1 2 3

PLATE 13. WORKING-OVER OLD ORCHARDS. Sixteen-year-old seedling, budded and topped. 1. Before beheading. 2. After beheading. 3. New growth three months after beheading.

from the buds after four weeks (the usual period) in a number of cases in the Pomona Valley in 1901, and they generally died, but in the same year when the bands were allowed to remain on the buds for six weeks the result was satisfactory.

Removal of the Tops.—There are three usual methods of removing the tops after budding: (1) the removal of the entire top at the time of taking the bands from the buds; (2) the removal of all branches but one, which is left to draw sap; and (3) the girdling of the limbs above the buds while still retaining the entire top for one year.

When the first method (illustrated in plate 13, and also in plate 14)

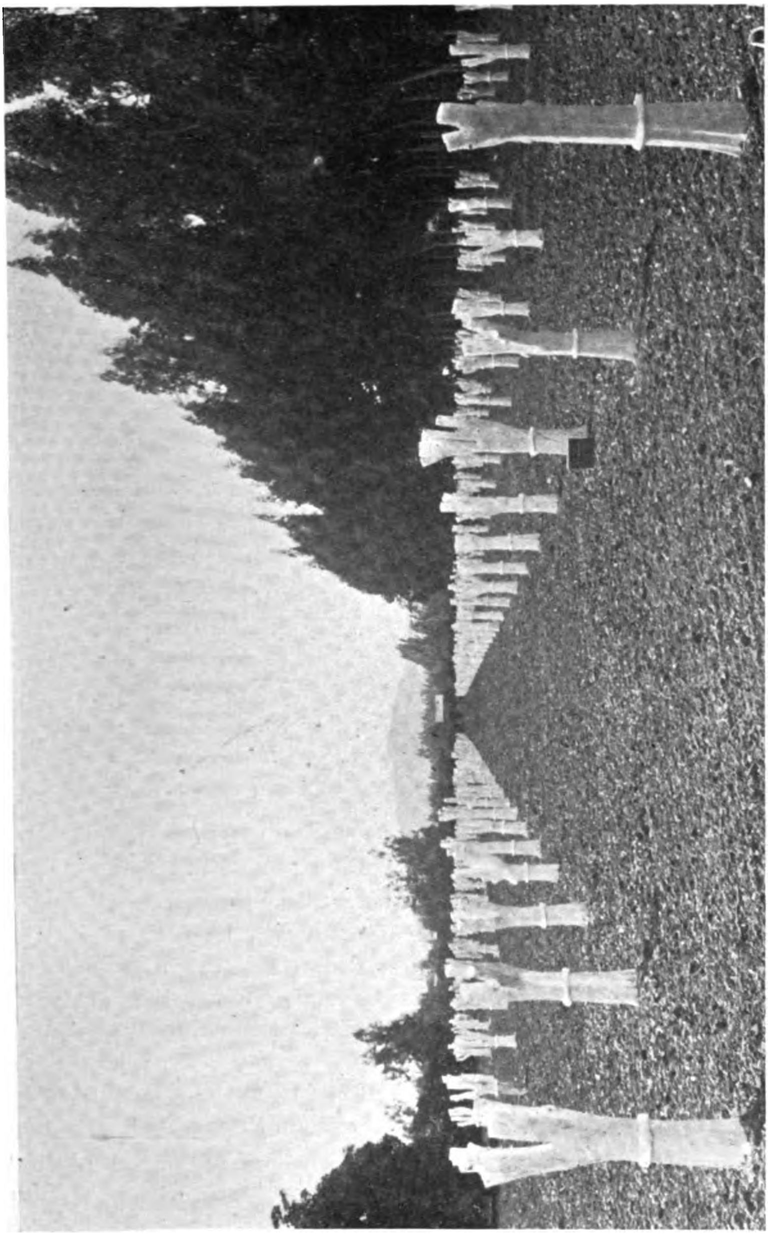
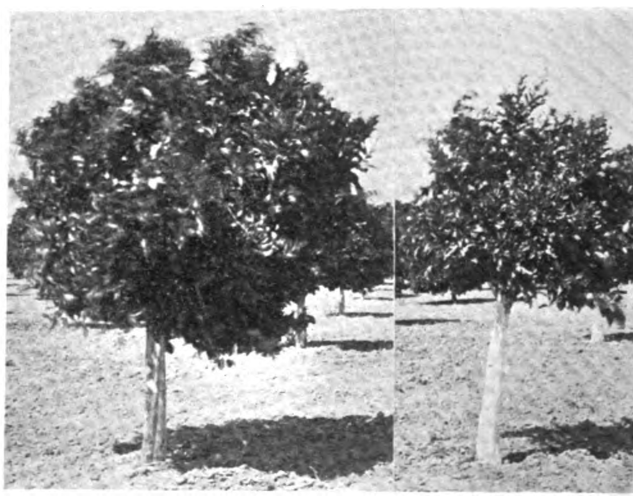


PLATE 11. WORKING-OVER OLD ORCHARDS. **Appearance of orchard on removal of entire top at time of taking bands from the buds.**

is practiced and proper protection is given to the buds and young top during the first year, better results seem to be obtained than by any other way. The new top receives the entire nourishment afforded by the tree; with frequent pinching-back of the new branches, the wood can be hardened and better matured before winter, and the leaves become thick and heavy, affording much frost-protection. This is shown in plate 15. Both trees were budded in May; No. 1 was topped in June at the time of removing the bands; No. 2 was topped in July, one month after bands were removed. The photographs were taken a year later, and are typical of five-acre blocks. But when this method is



1 2

PLATE 15. WORKING-OVER OLD ORCHARDS. 1. Topped when bands were removed. 2. Topped one month after bands were removed. Photographs taken one year later.

employed in frosty sections, the tops must be protected still further during the first winter. The young growth will be killed when the thermometer registers from 25° to 27° Fahr., and if the tops are killed back to the old wood, the trees will seldom or never become useful, often failing even to send out suckers. An illustration of this frost effect is shown in plate 16.

The value of protection to the young top during the first winter was shown by a lemon orchard, in a frosty location, that was budded-over to Washington Navel oranges. When the tops were removed, the growth from the buds was wrapped with palm leaves during the first winter; eighteen months after the trees were budded, they were past all danger from frost, and were large enough to produce a box of oranges per tree. (See plate 17.)

PLATE 16. WORKING-OVER OLD ORCHARDS. Frost effect on unprotected young growth.

PLATE 17. WORKING-OVER OLD ORCHARDS. Lemon stock 18 months after being budded to orange; in a frosty location, but protected by wrapping with palm leaves.

Seedling orange trees that were budded-over when sixteen years old, and were protected by nailing palm leaves to the trunks and by wrapping the palm leaves around the new tops, produced an average of eight boxes per tree during the first five years after they were so budded.

The second practice of *leaving a side branch on the tree* to "draw sap" is a safe method, and will sometimes save a tree if the buds fail to grow; but when budding is skillfully done there is no need of leaving side branches. (See plate 18.)

PLATE 18. WORKING-OVER OLD ORCHARDS. Pomelo budded to orange; leaving side branch to keep up circulation.

Girdling the branches above the buds after they have healed over and the bands have been removed, while leaving the tops on until after the first winter, is not practiced widely, but has some ardent advocates. The top when thus left continues to draw enough sap to keep alive, and to ripen a crop of early and poor fruit. The removal of such a top after the buds have made one year's growth is sometimes difficult without injuring the new head. The chief advantage for this method is that the old top forms a covering for the new head, obviating the necessity of wrapping it for protection against frost. Trees handled in this way (see plate 19) have made a better record than adjoining trees that had the tops cut off at the time when the bands were removed from the buds and were left unprotected during the first winter. (See plate 20.)

When the leaves of fan palms are used, the stems are tied around the trunks of the trees and the broad leaves are fastened around the tops. After spring frosts are over, the palm leaves are removed. Sometimes the palm stems are nailed to the trunks of the orange trees, which is more convenient than tying. Though not a praiseworthy method, yet this does not seem to injure the trees.

The old-time method of cutting off the entire top of a tree so as to bud upon suckers is now considered a poor way, as a year of time is thereby lost.

PLATE 19. WORKING-OVER OLD ORCHARDS. Top removed when buds have a year's growth; protection given thus against frost.

PLATE 20. WORKING-OVER OLD ORCHARDS. Top removed at time of budding; no protection made against frost during first month.

PRUNING AND SHAPING TREES.

The tendency of young trees of Washington Navel and some other varieties to assume a drooping habit when making a vigorous growth is due to the fact that the soft shoots are unable to support the weight of the large, heavy leaves. Mr. Reed writes: "It can not be expected that the soft, succulent shoots will grow upright when they are weighed down with the great fat leaves that vigorous young Navel trees always produce, but if they are pinched back they will soon begin to straighten up. If this method is followed, a Washington Navel tree can be made symmetrical and upright. I make it a point to visit every one of my young trees several times during the season and pinch back shoots."

Even trees that have been long in bearing will be benefited by pinching back every branch that takes too vigorous an upward growth. This pinching process is especially necessary with trees from one to five years old.

Pruning Bearing Trees.—The advantage of an upright tree over a drooping one is considerable when it becomes loaded with fruit. The crop is borne with less breakage of limbs, and not so much fruit is injured with the wind. After they are in full bearing, there seems to be no pruning that will promote the health of the trees or improve the crop, other than cutting out limbs that project abruptly from the side, or those that make a sudden skyward growth, and the constant trimming out of dead or stunted wood that is found on the inside of the trees.

If too close, the branches of a tree should be thinned out from the inside until the sunlight has had free access. This does not make any noticeable difference in the appearance of the tree, but makes it bear fruit on the inside. Such fruit is safe from sunburn and frost, and packs as "fancy" grade. By early attention to pruning, the trees need never be allowed to grow too close in the center.

Renewal of Tops.—There are some groves of old orange trees that do not respond to the best treatment that the owners can give them. Under such circumstances, the most effective way to stimulate new life and vigor is sometimes to remove the entire top, leaving enough of each of the main limbs to distribute equally the suckers that will afterward make the new top of the tree. If the tops are only thinned out and but partially cut back, there will be a proportionate amount of feeble growth and a corresponding lack of productiveness. An old orange tree will rapidly produce a new top, even when cut back to a mere stump. It is soon in a condition to bear again at its full capacity. When the roots are healthy and the soil is properly cultivated and fertilized, the orange tree appears able to produce several generations of tops on one stock. But it will generally be found that the trouble with old, non-productive trees lies in the root-system, or in the management of soil, or in both. Thorough investigation of roots and soil should be made before any severe cutting or pruning of the top is resorted to.

Except as noted in preceding paragraphs, all trees should be trained low for protection against frost, heat, and wind, and to aid the gathering of fruit. Heavily-laden branches are generally propped to prevent breaking down, as the loss from dropping and splitting is so great that the trees cannot be safely lightened by thinning of fruit when small.

CULTIVATION AND IRRIGATION.

During the past seven years the substation grove has been plowed deeply at least twice north and south one year, and twice east and west the next. Every year the plow turns up masses of fibrous roots that grow just below the reach of the cultivator teeth, in the strip of land between the trees in the rows running in the direction of the last plowing. These roots grow from five to twelve inches below the surface during the winter and spring when the soil is kept moist by rains. Their presence shows the upward tendency of the feeding roots of orange trees when left to grow naturally under favorable conditions.

The extent to which the root-systems of orange trees can be influenced by orchard treatment seems to be very limited.

The deep-rooting tendency of the sour-orange (plate 8) is observable in both light and heavy soils, while the roots of the sweet-orange, and in a lesser degree those of the pomelo (plates 6 and 7), grow near the surface in all kinds of soil during the seasons of their most rapid growth, and the only way in which they can be forced to a lower depth is to plow deeply and apply irrigation water as low as practicable. As orchardists can not with present facilities afford to plow deeper than ten or twelve inches, the fibrous roots will mostly be found just below that depth. Even after trees become old and well established, their fibrous roots continually seek the surface soil, unless deep plowing and deep irrigation are persistently practiced. One orchard near Pomona, which has been plowed deeply from the time it was planted and irrigated in deep furrows, bore four and a half boxes of fruit per tree at the age of eleven years. An adjoining orchard that was never plowed, but was cultivated frequently and irrigated in furrows made with a "bull-tongue" attachment, produced but three and a half boxes of poorer oranges at the same age. The former orchard is budded on sour-stock, which, as heretofore shown, roots deeply, and it received a liberal amount of fertilizers; while the latter orchard is budded on the shallow-rooting sweet-stock, and received but a moderate amount of fertilizers. The more productive of these two orchards evidently has the better root-system; it has also been plowed deeply and irrigated in deep furrows—therefore, it never shows the need of water before the regular irrigation date comes around. On the other hand, the less productive orchard, which is on surface-rooting stock and has received much shallower culture and watering, shows signs of drought before each irrigation date. In the case of orchards on the same stock, the value of deep plowing and deep irrigation is also very marked.

The So-Called "Hardpan."—The orange tree is a native of tropical forests, where it obtains warm soil and abundant moisture within easy reach. Its successful culture in the countries like California, which lack summer rains and moisture-laden atmosphere, is necessarily to some degree artificial and a notable triumph of modern horticulture. In order to achieve the highest results, it becomes more and more essential that the grower shall keep the soil in the most perfect condition, shall apply all needed water and plant-food in sufficient but not in excessive amounts, and shall pay especial attention to keeping the feeding roots as low as practicable and to preventing the formation of what is called "hardpan," but is only the well-known "plow-sole," aggravated by shallow irrigation.

"Hardpan," some growers say, appears now where it was never before known. The fibrous roots of orange trees run along its surface, and thus are subject to every vicissitude. It often happens that what orchardists call "hardpan" is only the firm layer of soil caused by uniform cultivation, or plowing, whether deep or shallow. The depth to which soil is stirred should vary from year to year; eight inches, twelve inches, ten inches, fourteen inches, and then eight inches again, would put an end to much of the present outcry against "hardpan." Cultivator teeth should also be kept sharp and should be "set down" to various depths so as to prevent the formation of "plow-sole" of any description, and to assist in breaking up that which former neglect has caused.

Very few orange groves have been planted upon true "hardpan," and if so planted have seldom succeeded. Only a few trees, such as our native oaks, are capable of thrusting roots through the iron-like layer of natural subsoil that is properly termed "hardpan." When found to exist, it should be deemed sufficient to debar citrus culture, unless so thin that, by boring or blasting, the root-system can be established in good soil below the "hardpan," or when it is so constituted that when kept irrigated the roots will penetrate it.

An instance of the latter occurred at Riverside, where Mr. Reed planted a few trees on a terrace bordering on an arroyo, and found what was reported as true "hardpan" near the surface. The trees received "an abundance of water over the whole area for a year," and it was then found that the roots had penetrated it to a considerable distance.

The term "irrigation hardpan" is quite generally used in the orange-growing district to describe the condition of some small areas in orchards where irrigation and subsequent culture have been careless, or where sufficient attention has not been paid to the difference of treatment required by lighter and heavier soils.

Of course very sandy soils can be handled sooner after irrigation than can heavier soils, and when a sandy piece of land containing areas of heavy soil is cultivated as soon after irrigation as the sandiest part will permit, trouble may be expected with the so-called "irrigation hardpan," by the puddling of the subsoil, partly directly by the plow, partly by the soaking-in of clay-water.

Value of Proper Cultivation.—It is usual for orchardists to put in a subsoil plow to help in breaking up the heavy spots of what is called "irrigation hardpan." But this difficulty can easily be overcome without using a subsoil plow, as was shown by the experience of Mr. W. J. Cox, of Glendora, Los Angeles County, who found that "irrigation hardpan" was forming in a part of his orange grove. He irrigated a few trees that were within reach of the domestic water-supply, and followed this up at the proper time with thorough cultivation. After each irrigation he cultivated a little deeper. As a result of deep irrigation and cultivation, the soil took in water as readily as ever and the trees regained their vigorous appearance. He simply used a chisel-tooth cultivator and plenty of water.

A somewhat different case was that of Mrs. McKenzie, of Riverside, whose orange grove failed to be profitable, though apparently well irrigated. This orchard had been cultivated to the same depth until a hard, clay "plow-sole" had been formed. The stratum of hard subsoil was several inches thick and contained a number of large surface roots. She wrote to the California Experiment Station, sending samples of soil for examination. It was found that the plow-sole prevented the irrigation water from reaching the deeper roots, and she was advised to plow the entire orchard, roots and all, as deep as the plow would go. This was done, much to the alarm of many growers, and great numbers of orange roots of all sizes were turned to the surface. Following further advice, she irrigated and cultivated the ground deeply, and the following season she harvested the largest crop ever taken from this grove.

The Glendora grove, to which allusion has been made, had had deep cultivation from the beginning, and the roots were mainly below the so-called hardpan. The McKenzie grove had many roots in the hard "plow-sole," so that the only remedy was to destroy these useless roots and force the growth of new and deeper ones, at the same time giving the irrigation water a chance to penetrate. This rather drastic root-pruning was necessary, and if the Glendora grove had been cultivated to a uniform depth a few more seasons, deeper plowing and the destruction of the surface roots would have become inevitable there also. The breaking-up of all hard layers of soil caused by improper cultivation or careless use of water is of the first importance to the health and profit of an orchard.

Reckless Deep Cultivation.—After Mrs. McKenzie's experiment at Riverside, previously mentioned, subsoilers of different forms were used, and the idea soon became common among growers that the deeper a plow could be run, the better would be the results that would follow. The injurious results of such practice can not be estimated without careful study of the root-systems of orange trees on various stocks and soils. A number of bearing citrus groves were so much injured by the reckless use of subsoil plows that the leaves of the trees actually wilted down immediately after the operation. In these cases, the sharp-cutting plow was run close to and on all sides of the trees. When trees over ten years of age, which have been subjected to uniform shallow plowing and irrigation, are submitted to such treatment, they probably lose at one blow not less than seventy-five per cent of their active roots. The shock is such that it would take several years of careful treatment to restore the trees.

Practical Notes on Deep Cultivation and Irrigation.—It is almost always more economical to use a subsoiler or plow where "irrigation hardpan" has been formed than it is to use the large amount of water necessary to soften it; but according to the best practice the deepening of cultivation should be gradual, and the implement should never run deeper than fifteen inches. One must remember that the really serious loss in sudden deep cultivation comes from the destruction of thousands of fibrous roots that grow from the hundreds of laterals branching from the large main roots.

If a plow is run to a depth of one foot, in three furrows, between the rows, and water percolates slowly for a long time through these furrows, no need can arise for a subsoiler. "Irrigation hardpan" within reach of the plow simply shows, as has been said, that too shallow and too uniform cultivation has been practiced. In that case the entire surface should be thoroughly broken up, and irrigation in deep furrows after this will restore the proper conditions.

Experience also shows that when the water is slowly run in deep furrows for a long time and the greater part of the surface is kept dry and is deeply cultivated, better results are obtained than when the basin or block method, or even the shallow-furrow plan, is used, even though they are followed by deep cultivation. When the water is applied below the first foot of soil, and the soil above is kept comparatively dry, there is nothing to attract the roots to the surface; and when the water is thus applied, a team can be driven along the dry strips of land between the furrows, and with a harrow or other appliance the dry soil can be dragged into the wet furrows, to lessen the evaporation, immediately after the irrigation water is turned off. By any other system, it is absolutely necessary to wait at least twelve hours, and sometimes much longer, before a team can be driven over the ground. Then, too, when a soil irrigated by these more wasteful methods has been cultivated, it is still moist near the top, and is soon filled with a mass of new roots so close to the surface that they must be destroyed.

Waste from Evaporation of Water.—Water applied to the soil sinks and spreads. Some of it is being taken up by the still dry soil underneath and at the sides long after the last drop is visible. Some of it, too, is being drawn back to the surface, and thence evaporated into the warm air. Irrigation after sundown has some distinct advantages, if the water can be handled. Sub-irrigation upon soils adapted to its use is the ideal system of applying water, and greatly lessens waste. Orange roots will not enter a pipe-line unless it is full of water all the time. If the pipe is on a grade and open at bottom and top so that air passes through it, there will never be trouble from orange roots. Valves, once thought necessary, are not now used. The high cost of the present sub-irrigation systems places them beyond the reach of most orange-growers.

Spread of Water from Deep Furrows.—The accompanying diagrams (plate 21) show the extent to which water from fairly deep furrows penetrates the sandy soil and the heavy loam of the substation. A moment's study of them will convince any one that the only way in which to lessen waste in surface irrigation is to let the water flow slowly through as deep and narrow furrows as practicable, thus making a larger cross-section of wet soil, even narrower at the surface than in the chart, and checking the evaporation by filling the furrow with dry earth and by cultivation at the earliest moment.

Examining these suggestive diagrams of soil-saturation, let us first call attention to the three showing the spread and descent of water on the heavier soil. Here it has spread much more slowly and to a less extent than in the case of the adjacent sandy land. Even after two days' run of water (of twelve hours each) and seventy-two hours further delay (see No. 3), the total sectional area of saturation is hardly more than half as great, covering about sixteen square feet, as against about thirty square feet on the lighter, more porous soil (see No. 6). A still deeper and narrower water channel is highly desirable on this heavier soil. Instead of eight inches, it might well be sixteen or eighteen, which would make the cross-section, No. 3, nearly a foot deeper, and narrower on the surface.

The cross-sections on the sandy soil show that the eight-inch furrow is practically sufficient to carry the water well down into the soil. A deeper, narrower channel even here will result in economy in the use of

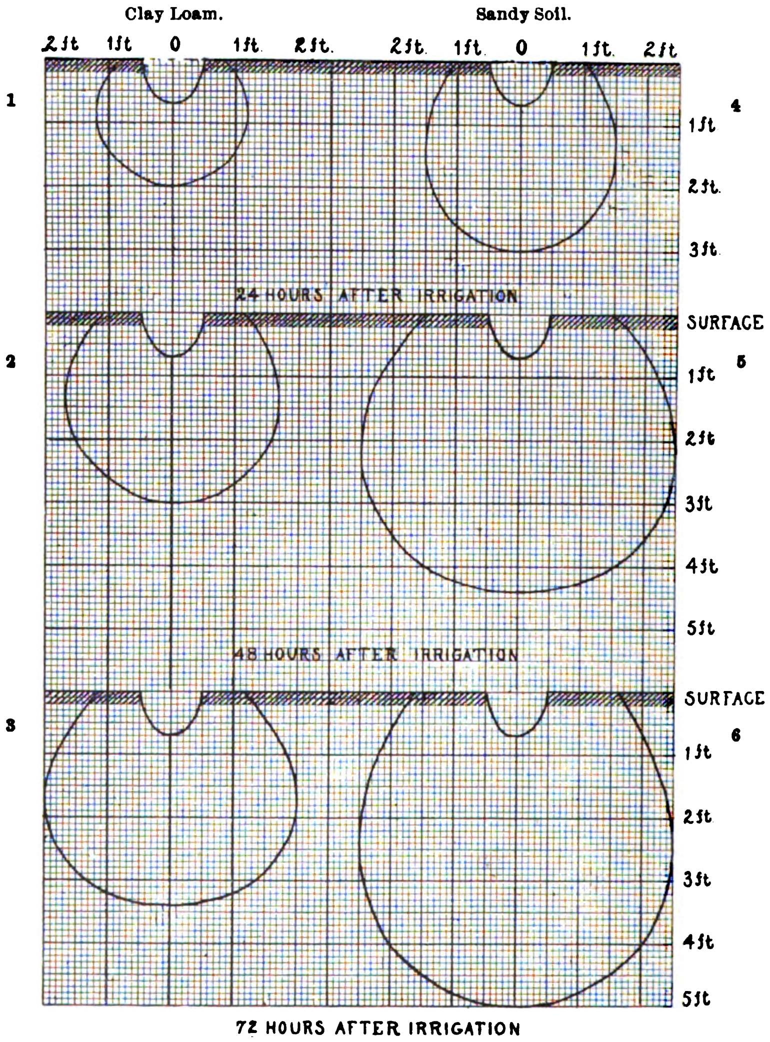


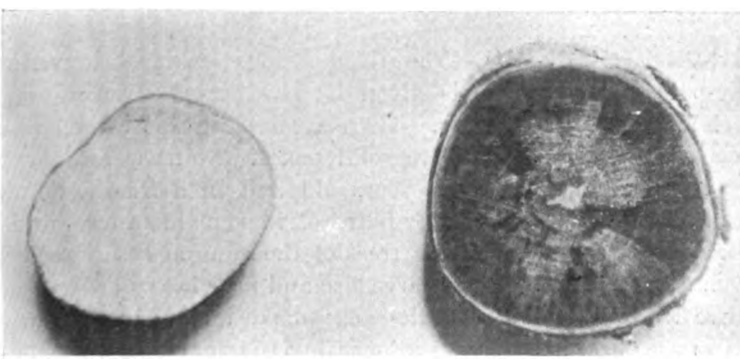
PLATE 21. PERCOLATION EXPERIMENTS. SPREAD OF WATER FROM DEEP FURROWS IN HEAVY AND LIGHT SOILS.

water, a smaller flow producing as large an area of saturation as that shown in diagram 6, with less surface. These two sets of illustrations of the results of irrigation in furrows on different soils, under conditions otherwise practically identical, explain and enforce the entire argument respecting deep irrigation set forth in this bulletin, and long and earnestly recommended by Professor Hilgard.

NOTES ON DISEASES OF THE ORANGE.

Three diseases of the orange tree are widely known in California. First in importance come two kinds of "gummosis," or "gum disease," that which attacks roots and trunks just above the surface of the ground, and, second, that which is called "scaly bark" gum disease. The former has existed in Southern California since 1875. It makes its appearance where the ground has been allowed to remain wet close to the trees for long periods. E. W. Holmes, of Riverside, says that he has seen fifteen per cent of a seedling orange orchard become affected after heavy applications of nitrogenous manures followed by irrigation close to the trees during hot weather. All the affected parts should be cut out so as to remove every trace of diseased tissue. In some cases this requires repeated cuttings and the use of an antiseptic wash.

The "scaly bark" gum disease is the most prevalent form in Southern California. It attacks the trunk of the tree, and also some of the



a *b*

PLATE 22. Gum Disease of the Orange Wood.
a. No disease. *b*. Darkening of wood by disease.

branches. If not checked at once it will kill the tree. The new bark is unhealthy, and the disease soon penetrates to the center of the limb or the trunk of the tree. (See *b*, plate 22.)

Antiseptic Washes for Gummosis.—The treatment for both forms of gum disease is the same. Use one part of crude carbolic acid to four parts of water. The Florida Experiment Station uses a wash of lime, crude carbolic acid, and salt. Slack one peck of lime in two gallons of water, and add, of crude carbolic acid four ounces, and of salt three pounds. If too thick, add a little more water.

In cases of the root form of gummosis, the soil should not be thrown back upon the roots after cutting out the diseased tissue, until the wounds begin to heal. It is necessary, however, to shade the roots from the sun. The diseased wood should be burned. Removal of the entire tree is often wiser than trying to cure the disease.

Value of Sour-Orange and Pomelo Stocks.—The "scaly bark" form of gum disease has not been observed in California on the Florida sour-orange stocks. Such trees, budded to Navel oranges two feet or more from the ground, are growing near the substation. Some of them have diseased trunks and branches, but in no case has the disease been found extending down to the sour-stock. Evidently there would be no advantage in using this resistant stock in low-budded nursery trees, but sour-stocks might be planted in the orchard and allowed to form the main branches of the future tree. Then should the "scaly bark" make its appearance, a few branches might be destroyed, but the trunk would remain sound. Since the sour-stock has not given universal satisfaction in Southern California, the pomelo, which seems but little less resistant to "scaly bark" than is the sour-orange, and is a more universally vigorous grower, may be used. The sweet-orange stock is the poorest of the three.

The "Die-Back" Trouble.—The third serious trouble is exanthema, or "die-back." This name is given to a weakness affecting orange, lemon, and other orchard trees. There are several especially bad cases in the San Gabriel Valley, where solid blocks of citrus trees are now utterly worthless. Trees seven years old and in a frostless location have not attained a height of over four feet, in some instances, and bear little or no fruit, while adjoining trees of the same age and seemingly under similar conditions are of large size and bear heavy crops.

Orange trees affected with "die-back" make an apparently healthy growth in the spring and early summer, but the young shoots soon turn yellow, the leaves drop off and the twigs die back to the older wood, from which a brown granular substance exudes. In a season or two, this older wood also dies. Adventitious buds keep developing at the axils of the leaves, until at the end of the season there are small knots, where there should be healthy lateral branches. (See plate 23.) Experiments with Bordeaux mixture and carbonate of copper have been made in a badly affected grove near Pomona. The work so far has shown no appreciable results, but it has not yet been carried through one season.

[In almost all cases of "die-back," examination has shown some fault in the subsoil, which puts the roots under stress. Such fault may be an underlying hardpan or impervious clay, pure and simple; or it may be excessive wetness or dryness of the substrata surrounding the deeper roots; or the rise of bottom water from below, as in cases of over-irrigation. The true "die-back" is not properly a disease, but simply the manifestation of the distress felt by the root-system underground.

The first thing needful is to dig down and examine the roots, and then to relieve whatever fault may be found, if possible; which may not always be the case. Sometimes an appearance similar to the "die-back" is caused by the roots encountering a marly stratum, which is apt to stunt the growth of the tree, causing it to put out a multitude of small, thin branches, and sometimes causing the tips to die off. For this form of the trouble there is no permanent remedy; the trees should

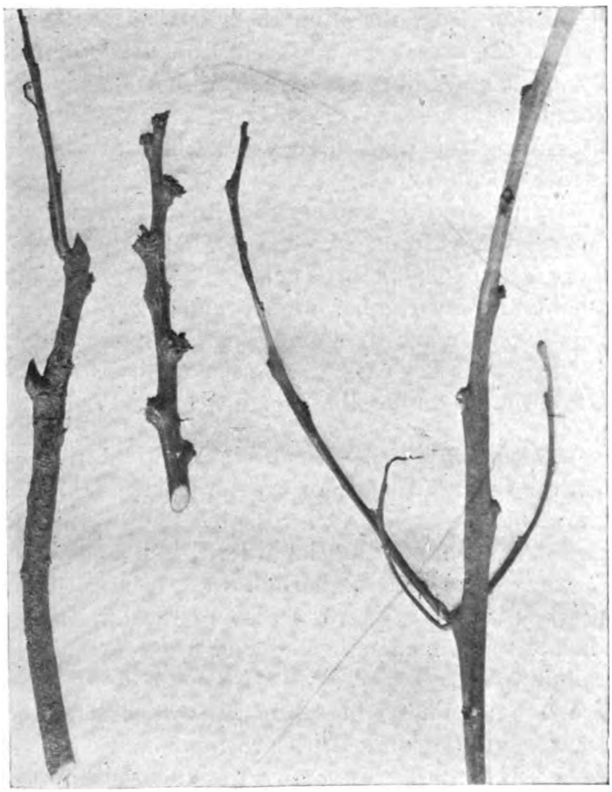


PLATE 23. "DIE-BACK" OF ORANGE LIMBS.

never have been planted in such ground, any more than in such as has shallow-lying hardpan or clay. (E. W. H.)]

["*Mottled Leaf.*"—Closely related in its causes to the "die-back," and sometimes accompanying it, is the "mottled leaf" trouble. It may be properly called "partial chlorosis" of the leaves, and on the basis of that designation it has been attempted to treat it like the corresponding human ailment, with iron tonics and fertilizers. But in every case that I have closely examined, and in most of those reported to me by others who have made such examinations at my suggestion, the cause was not lack of nourishment that could be remedied by such means, but simply an improper condition of the root-system, especially of the deeper roots. When a thriftily growing tree suddenly stops and begins to show mottled leaves, it is clearly not because of lack of nourishment in the soil, but because some of the physical requirements of the tree's well-being have ceased to be satisfied. In such case fertilization can afford but temporary relief, if any.

The commonest cause of mottled leaf is a layer of dry gravel or sand reached by the tap-roots, throwing them out of healthy action. Of course the same effect may be expected from the exhaustion of the usual supply of moisture in the substrata, which has not been made up for by the comparatively scanty irrigation permitted by the diminished water-supply during the past three years. The cause of the present great prevalence of mottled or yellow leaf in the citrus orchards is probably a parallel to the wholesale dying-out of vineyards in the Santa Clara Valley, regarding which a special bulletin (No. 134) was issued by this Station some months ago.

Quite probably, however, other unfavorable conditions affecting the roots, such as alkali, marl, or a hardpan layer, may in many cases produce this effect. In any case, the cause should be sought for at the roots before deciding upon possible remedies. (E. W. H.)]

Difficulty of Replacing Trees.—It is difficult to install new trees in an orchard when the surrounding trees are large. In fact, it is necessary to dig very large holes and fill them with rich earth. Such trees should be given extra irrigation and additional fertilizers, besides what is regularly given to the older trees. This should not be applied merely to the space around the newly-set trees, but also to the adjoining older trees, as it is needful to furnish enough food and water for all the roots that fill the surrounding soil.

All orchardists find trouble in filling gaps where trees have died or become diseased, but the difficulties are more marked in the case of citrus fruits than with the deeper-rooting deciduous species. A selection of especially healthy specimens from the nursery will help. Then, as noted, the best of culture and all the fertilizers that can be assimilated are needed. Lastly, the judicious root-pruning of large adjacent trees may assist those newly planted.

CALIFORNIA ORANGE AND LEMON STANDARDS.

Citrus-fruit culture includes much that can find no place in so brief a bulletin, but some of the more pressing and practical problems have been discussed. The interesting topic of wind-breaks and hedges for protection against frost and storms has not been taken up, nor has the group of questions relating to the handling and marketing of crops.

But there is often an inquiry made respecting the official scale used by judges of citrus fruits at fairs and other competitions. A standard scale of points is that adopted by the Los Angeles Chamber of Commerce in 1894 and the following year by the Southern California Fruit Exchange. It seems well balanced, comprehensive, and practical. At the present time it is the most widely used official scale in California.

The following rules have been adopted by the executive committee of the Los Angeles Chamber of Commerce in reference to the judging of citrus fruits:

No person shall be allowed to serve as judge in any class in which he is an exhibitor.

Any exhibitor who addresses a judge while the latter is in discharge of his duty, will be debarred from competition.

A majority of the judges present shall constitute a quorum for decision in any class.

Preliminary Classification.—Season: Early, from December to April; middle, February to July; late, June to December.

Size: Large; medium; small.

(The managing committee from each competing state or section is to nominate varieties to any or all of the above classes, with months, and, when practicable, days, for tests of its own fruit. Fruit to be judged by standards of its class. So far as practicable, no committee is to judge fruit of more than one size, as per above classification.)

ORANGE SCALE TO BE USED.

Divisions of scale: Size, form, color, weight, peel, fiber, grain, seed, taste; to be considered in order named. Credits to be units and tenths thereof, to be expressed decimally; possible total to equal 100.

1. *Size.* Possible credits, 10.

Standards:	Large,	126's, $3\frac{1}{4}$	inches in diameter.
	Medium,	176's, $2\frac{15}{16}$	" " "
	Small,	250's, $2\frac{7}{16}$	" " "
	Tangerines, etc.,	$2\frac{1}{8}$	" " "

One unit discount for each $\frac{1}{8}$ inch deficiency or excess in any size.

2. *Form.* Possible credits, 5.

Standards: Round, oval, ovate, pyriform.

Discount for lack of symmetry and for form blemishes. Navel marks not to be discounted, except when of abnormal size or bad form.

3. *Color.* Possible credits, 19, divided as follows: Bloom, 2; peel, 10; flesh, 7.

Standards: Bloom to be perceptible, and to be discounted according to degree of deficiency or of injury thereto; peel to be of rich, deep orange color, in natural condition, and to be discounted according to degree of deviation therefrom, one or more points; rust, scale, and smut to be discounted five to ten points, and fruit that gives visible evidence of having been cleaned of the same to be subject to equal penalty; also peel that has been rubbed or "polished," giving a gloss at the expense of breaking or pressing the oil-cells, to suffer same discount. Flesh to be rich, clear, and uniform, in any of the shades common to fine fruit. (Omit consideration of "flesh color" until after concluding division 5, "peel.")

4. *Weight.* Possible credits, 10.

Standards: Specific gravity, 1, with buoyancy of $\frac{3}{4}$ oz. allowed to "large" fruit, $\frac{1}{2}$ oz. to "medium," and $\frac{1}{4}$ oz. to "small," all without discount.

One point to be discounted for first half-ounce of buoyancy in excess of allowance, and thereafter two points for each additional half-ounce. (*Note.*—Buoyancy may be easily determined by clasping weights to the fruits with light rubber bands, and then placing in water.)

5. *Peel.* Possible credits, 10, divided as follows: Finish, 3; protective quality, 7.

Standards: Of finish, smoothness and uniformity of surface, and pleasant touch; of protective quality, firm and elastic texture, abundant, compact, and unbroken oil-cells; and $\frac{1}{8}$ to $\frac{3}{16}$ inch thickness.

Discount one half point for first $\frac{1}{32}$ inch above maximum or below minimum, and two points for second $\frac{1}{32}$ inch, provided that to long-picked and fully-cured oranges the minimum shall be lowered to $\frac{3}{32}$ inch; and that to fresh-picked and to slightly-cured "large" fruit the maximum shall be raised to $\frac{1}{4}$ inch.

Breaking of oil-cells, breaking of peel and abrasions of same to be subject to one to ten discounts, according to degree.

(Here consider "Color of Flesh"—see division 3.)

6. *Fiber.* Possible credits, 8.

Standards: Septa delicate and translucent; maximum diameter of core, $\frac{3}{16}$ inch in "large" fruit and $\frac{1}{8}$ inch in other.

7. *Grain.* Possible credits, 4.

Standards: Fineness, firmness, compactness.

8. *Seed.* Possible credits, 4.

Standard: Absence of seed.

Discount one point for each seed. Each rudiment to be considered as a seed if any growth has been developed; otherwise allowed without discount.

9. *Taste.* Possible credits, 30, divided as follows: Sweetness, 15; citrous quality, 15.

Standards: Clearness and definability of elements; sweetness rich, delicate rather than heavy; citrous quality, pronounced.

Deficiency or absence to be cause for discounts against any element, and excess to be like cause against sweetness, and against acid in "citrous quality."

Staleness and flavors of age or decay to be discounted from aggregate of points in this division.

LEMON SCALE.

Divisions: Size, form, color, weight, peel, fiber, grain, seed, taste.

Rules of counts and discounts as in scale for oranges. Total of possible credits, 100.

1. *Size.* Possible credits, 10.

Standards:	Large,	250's,	$2\frac{3}{8}$ inches in diameter.
	Medium,	300's,	$2\frac{1}{8}$ " " "
	Small,	360's,	$1\frac{7}{8}$ " " "

All sizes between 250's and 360's allowed.

Larger fruit to be discounted one point for each $\frac{1}{4}$ inch in excess. Smaller to be discounted one point for 400's ($1\frac{3}{4}$ inches) and four points for 450's ($1\frac{1}{2}$ inches).

2. *Form.* Possible credits, 5.

Standard: Oblong, with allowance of well-formed points at stem and tip. Symmetry required.

3. *Color.* Possible credits, 15.

Standard: Bright, clear lemon.

Discounts according to degree for green splashes, dashes of bronze, or deep shades, or for sunburn.

Rust, scale, and smut, with fruit that gives evidence of having been cleaned of the same, to be discounted five to ten counts.

Rubbing or dusting, if heavy enough to press oil from the cells, to be causes for discount.

4. *Weight.* Possible credits, 10.

Standard: Specific gravity, 1 (equal to that of water), with buoyancy of $\frac{1}{2}$ oz. allowed to "large" lemons and $\frac{1}{4}$ oz. to "medium" and "small," all without discount.

One point to be discounted for first $\frac{1}{2}$ oz. excess of allowance, and two points for each $\frac{1}{2}$ oz. thereafter.

5. *Peel.* Possible credits, 10; subdivisions of which are: Finish, 3 credits; protective quality, 7 credits.

Standard: For protective quality, to be strong, elastic, and reasonably firm texture; abundant, compact, and unbroken oil-cells; and thickness of $\frac{3}{32}$ to $\frac{3}{16}$ inch.

To be discounted two counts for first $\frac{1}{32}$ inch below minimum, and five counts for second $\frac{1}{32}$ inch; one count for first $\frac{1}{32}$ inch above maximum, and two for each succeeding $\frac{1}{32}$ inch.

Fresh-picked lemons not allowed.

6. *Fiber.* Possible credits, 8.

Standard: Septa delicate and translucent. Core not to exceed $\frac{3}{16}$ inch in "large" and $\frac{1}{8}$ inch in "medium" and "small" fruit.

7. *Grain.* Possible credits, 8, divided as follows: Fineness, firmness, and compactness, 4 credits; color, 4 credits.

Standard: Grain to be water-colored, shading to blue rather than to gray.

8. *Seed.* Possible credits, 4.

Standard: Absence of seed.

One half point to be discounted for each seed. (A discount of $\frac{1}{4}$ credit for each seed is now recommended as sufficient.)

Rudiments are to be considered as seed if any growth has been developed; otherwise allowed without discount.

9. *Taste.* Possible credits, 30, divided as follows: Acidity, 20 credits; absence of bitterness, 10 credits.

In interstate competitions the standard of acidity shall be the highest per cent of strength of acid found in any fruit, determined by chemical test. In other competitions such tests may be applied as committees or competitors may require.

Bitterness to be determined by slicing fruit (including peel) thin, covering with hot water, and cooling slowly; to stand twenty-four hours when practicable (no sugar to be used). Should *a trace* of bitterness appear to the taste, discount one point; should the bitterness be *fairly defined*, discount two points; if *pronounced*, discount five points; and if *strong*, ten points.

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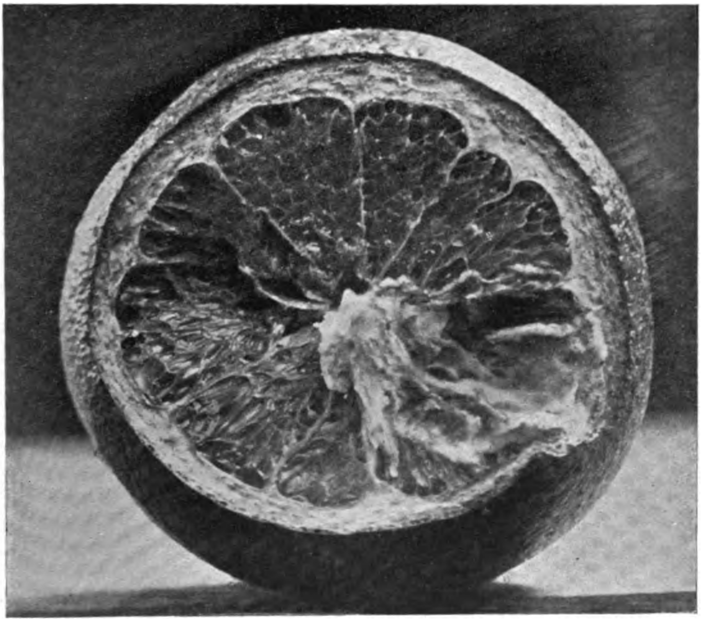
E. W. HILGARD, Director.

ORANGE AND LEMON ROT.

BY C. W. WOODWORTH.



NAVEL ORANGE, ONE FOURTH SHOWING THE EFFECT OF THE ROT.

BULLETIN No. 139.

(Berkeley, February, 1902.)

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ORANGE AND LEMON ROT.

By C. W. WOODWORTH.

The present season has been more than usually favorable to the decay of oranges, especially in early shipments. Every year the loss from the rotting of both oranges and lemons is very considerable. The cause of the rot and the precautions that should be taken to avoid the trouble are very rarely understood by those who handle the fruits; and there can be no doubt that a fuller knowledge of the subject would enable growers and shippers to avoid much of the loss. The present bulletin is prepared in response to requests from numerous growers for information on this subject.

The Cause.—The cause of the rot of oranges and lemons is the growth, through their substances, of a mold fungus known scientifically under the name of *Penicillium digitatum.* The growth of this plant within the fruit causes a softening and breaking down of the tissue, a very characteristic change in the flavor of the juice, and sooner or later a very pronounced discoloration of the affected part. The fungus belongs to a genus consisting of a number of well-known species, all having much the same manner of growth and producing decays on various substances. The name "blue mold" applies to the whole group. The best known species is *Penicillium crustaceum,* or, as it is more commonly called, *Penicillium glaucum.* This species is one of the common forms of rot-producing fungi that attack deciduous fruits, but it is probably even better known from its attack upon all manner of substances in the household, such as cooked foods, clothing, etc. While *Penicillium crustaceum* is thus found in a great variety of situations, it appears that *Penicillium digitatum* attacks only citrus fruits, confining itself wholly to these.

Nature of the Fungus.—The form of the fungus while it is growing through the tissue of an orange is that of innumerable fine white threads, known as "vegetative or growing mycelium," the individual threads being called "hyphæ." (Plate 1.) These hyphæ penetrate the fruit in much the same way as the root-hairs of higher plants penetrate the soil. Indeed, they are quite similar, except that the hyphæ are not attached to a more complicated organ like the rootlet from which the root-hair

PLATE 1. Vegetative mycelium from a culture of the fungus in water. Very much magnified.

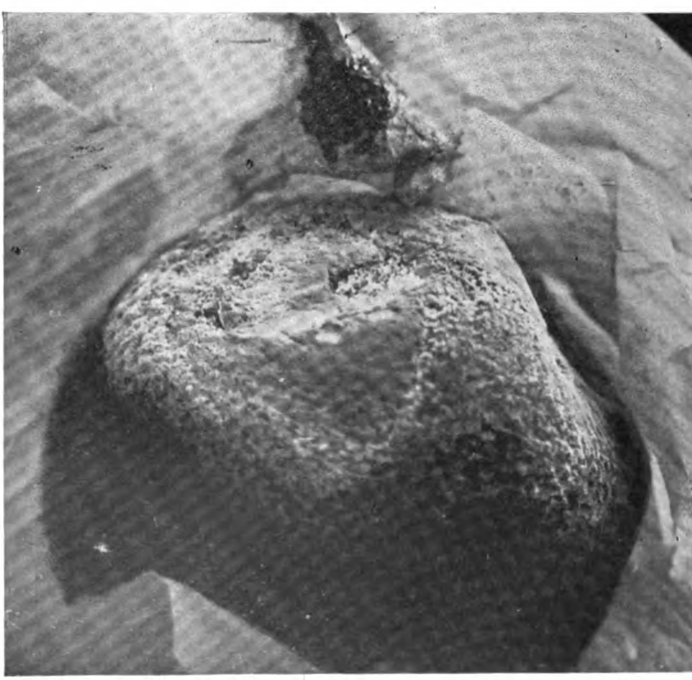

PLATE 2. Rotten orange, partly unwrapped, showing mold in white and blue condition.

springs. After the vegetative mycelium has somewhat exhausted the substances of the fruit, or if the latter becomes too dry for rapid growth, the fungus prepares to develop a form of fruit of its own. Fruiting hyphæ grow outward to the surface of the fruit, or, as is sometimes the case if there is a cavity within the fruit, they grow to the surface of the cavity and there form the *fruiting mycelium.* This is a dense mass of threads, white in color and soft and downy in texture. (Plate 3.) It is this stage of the growth that the growers call "white mold." It is merely a stage in the development of the fungus following the growth of the vegetative mycelium within the fruit, and the fruiting hyphæ are, as it were, the fruit spurs upon which the crop of the fruit of the fungus will be borne. The fruit of the fungus consists of minute, oval bodies, called spores, of dull, greenish-blue color. When they become numerous enough to hide the white mycelium upon which they are borne, the whole surface changes to blue, and it is then called "blue mold." (Plate 2.) The fruiting hyphæ producing the spores first divide into a number of branches, suggesting the name of the species ("digitatum," or fingered), and each of these branches as they increase in length become constricted, and finally divide into a large number of oval fruits, the *conidia-spores,* which for a long time hang together like a string of beads. (Plate 4.) They are easily broken apart, however, and produce then a fine powder that can be carried by the wind, and so are distributed far and wide.

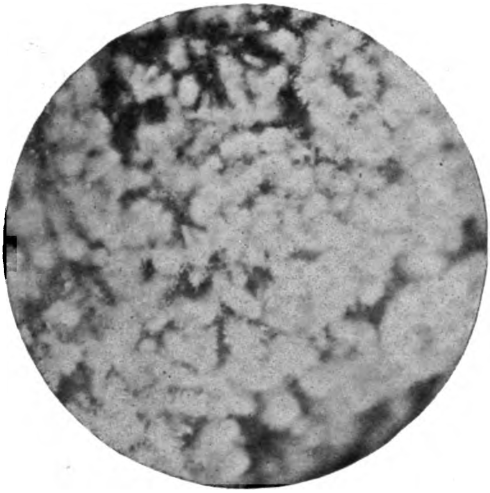

PLATE 3. Fruiting hyphæ in the "white mold" condition. Surface view as seen under the microscope. The same fruit shown in Plate 2.

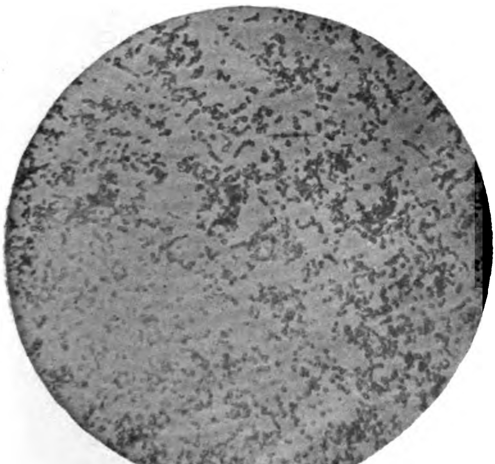

PLATE 4. Conidia-spores—still more enlarged.

There is another form of fruit produced by plants of this genus *Penicillium*, known as the *asco-spores*, being formed in little sacks called *asci*; but they occur only rarely, and, as far as we know, have not been recognized in this species. They doubtless occur, however, and enable the fungus to pass seasons that would kill most of the conidia-spores. The conidia-spore is the means of rapid reproduction, and the only one that is highly significant from the practical standpoint, because it is responsible for practically all of the infection of our fruit with the rot disease.

When and Where It Enters the Fruit.—The rot of citrus fruit is not

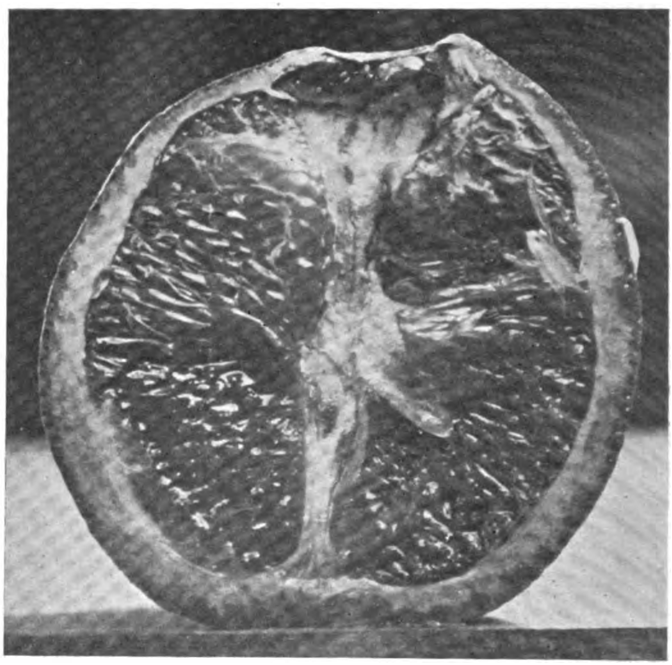

PLATE 5. Navel orange, showing rotten spot.

usually a disease of the orchard. In lemons the infection occurs almost entirely in the curing-house; and in oranges, as a rule, after they are packed and on their way to the East. Navel oranges, however, very often come into the packing-house badly infected by the disease. The trouble begins at the navel end, and may be scarcely visible from without; though commonly a slight split, or perhaps a little gum, will indicate the point of entrance of the fungus. (See Frontispiece and Plate 5.) In this case the trouble clearly arose in the field, and even began before the fruit was ripe. It is usually confined to a limited part of the fruit, perhaps the upper end of one or two sections, and very often produces spores within the cavity caused by the shrinkage of the affected tissue, so that the affected part may be badly discolored. In any citrus fruit a bad wound of the surface is apt to be followed by the development of the disease in the tissue just beneath, with the general characteristics specified above as occurring in Navels.

In the packing-house or in transit the point of attack may be the navel end, but it is more commonly where two fruits are pressed together. Usually only one of the fruits so touching is affected at first, though after it becomes thoroughly rotted the disease usually communicates to the other. If the conditions are favorable to the growth of the fungus, it may spread from a single affected fruit to all those adjacent, and in time to the whole box.

How It Enters the Fruit.—This disease, being entirely a matter of the fruit and belonging particularly to ripe fruit, evidently always gains its entrance to the fruit from the outside and never from the tree. The conditions necessary to accomplish this are:

First—That the spore of the fungus should rest upon or near the surface of the fruit. It may be carried there by the wind, or by touching decayed fruit upon which the spores are being produced.

Second—Sufficient water upon the surface of the fruit to cause the germination of the fungus.

Third—The right condition of temperature. The fungus will grow in such a range of temperatures, however, that this condition may be considered to be practically always present.

The germination of the spores of the fungus is thus seen to be much the same as the germination of the seed of a higher plant.

The reason that the navel end is particularly liable to the attack of the rot fungus is that in case a drop of moisture finds its way within this structure, it is less liable to rapid evaporation, and so favors the germination of any spores that may also find their way there. The same explanation accounts for the common abundance of this fungus in fruit with broken skin. The point at which moisture will accumulate and remain longest when fruit is sweating after packing, or while it is stored in the packing- or curing-house, is the point where the fruit touches an adjacent fruit; and at this point, therefore, the germination of the fungus most commonly occurs.

PREVENTIVE MEASURES.

From the above review of the manner of growth of the fungus producing the rot of these fruits, it is evident that our preventive measures must lie wholly along one of two lines: either by preventing the spores from gaining access to the surface of the fruit, or by the prevention of the germination of the spores after they are there. For the latter purpose several methods have been employed, usually without knowledge of the reason of their efficiency, and therefore often in a manner to defeat the very object sought. Those that have proven valuable are Refrigeration, Ventilation, and Wrapping.

Effects of Refrigeration.—One of the most available means for absolutely preventing the growth of the fungus, even though abundant upon the surface of the fruit, is to so lower the temperature where it is stored that the fungus will not grow. This method is followed very largely by shippers of green deciduous fruits, who have to contend against the closely related *Penicillium crustaceum.* If sufficient refrigeration is maintained, the fruit will be entirely safe from the attack of the fungus. In the use of refrigeration it should be clearly understood that the cold temperature is likely to condense a large amount of water upon the fruit, and as soon as the temperature is allowed to rise to the point where the fungus can grow, the conditions are extremely favorable for its rapid germination. This has given rise to the belief of many that fruit taken out of refrigeration is much more subject to rot than it was before. The skin may have really become softened by the water during refrigeration, so that this may in some measure be true. The common experience that washed fruit rots worse than that which is brushed dry, may be true for a similar reason. But in any case, the presence of water upon the fruit is always essential for the entrance of the fungus; and if fruit taken from refrigeration is immediately thoroughly dried by arranging for sufficient ventilation, there would be no greater susceptibility on account of the cooling. The use of refrigeration for citrus fruits will probably never be resorted to as extensively as for deciduous fruits, for the reason that the control of rot is not so difficult a matter.

Effects of Ventilation.—The use of ventilated cars, or the ventilation of the curing-house, is chiefly calculated to prevent the rot by carrying off the moisture that may accumulate on the fruit in the sweating process, or on account of the rapid lowering of the temperature. The cooling that is accomplished by the evaporation of this moisture is sometimes thought to act like refrigeration, and may, it is true, slightly decrease the rate of growth of the fungus after it germinates, but can not produce a temperature low enough to prevent its germination and growth. Certainly, the important matter in ventilation is the rapid removal of any condensed moisture that may gather on the fruit. If this moisture is removed promptly enough, so as not to give time for the germination of this mold fungus, the fruit will not decay, but will stay sound until it would ultimately dry up and mummify.

The problem in ventilation, then, is to maintain the mean, and avoid on the one hand too much drying, and on the other the presence of water for any considerable period upon the surface of the fruit. In small lots this is not particularly difficult, but in larger rooms there is some difficulty in securing a uniform ventilation; and therefore it is desirable, especially in curing lemons, that the temperature be kept as uniform as possible; particularly avoiding rapid lowering of temperature that might result in the deposition of water on the fruit.

Effects of Wrapping.—The practice which is almost uniformly adopted for citrus fruits, and which is rapidly extending also to deciduous fruits, viz., wrapping them in tissue paper, is an extremely efficient means of decreasing danger from rotting. The reason for this is that the paper absorbs water very freely and will take up a very considerable quantity. The paper will have to become very wet before it will give up enough to the spores of the fungus to permit them to germinate, and so it regulates the matter to a large extent; because when the temperature falls the paper merely becomes moist, and when the temperature rises this moisture is evaporated, and if there is fair ventilation it will be carried off and the fruit never become really wet. If the fruit sweats too much, however, owing to poor ventilation or rapid lowering of temperature, the paper will not be sufficient to prevent the accumulation of the water on the fruit and the germination of any spores that may be there. Only within certain limits, therefore, is the wrapping of fruit a preventive of infection by the fungus.

DESTRUCTION OF THE SPORES.

Thus far we have considered measures that have been employed to prevent the germination of the spores. Quite as important a matter is that of decreasing their abundance. This is a subject that has not been given the attention that it should have. I doubt if there is a packing-house in the State in which, in the midst of the season, the odor which is so characteristic of the spores of this fungus is not at once evident to every visitor. It would appear almost surprising if a single fruit could escape the presence of the spores of the mold upon its surface if it passes through some of the packing-houses in which the dust is so filled with them. The means that may be employed to diminish the number of spores in the packing- or curing-house are of three kinds: disposal of infected fruit, disinfection of the house in summer, and the use of sulfur.

Disposition of Decayed Fruit.—It is a common practice to throw decayed fruit in a pile in the immediate vicinity of the packing- or curing-house; and here it continues to decay and produce countless millions of spores, which are freely carried by the wind, and to this is due the thorough infection of the atmosphere, referred to above. There is no means better calculated to disseminate the disease than this practice. Fruit should never be allowed to become "blue." By the time it reaches the white-mold stage it should either be destroyed by fire, or, what is probably more feasible, be buried. If it is buried deep enough, so that it will not be turned up by plowing, or in any other manner, the decay of the fruit will be completed, and in time the spores of the fungus will disintegrate and the disease will not spread. When the fruit is stored in bins for some days, so that infected fruit will have time to become moldy, these moldy fruits should be removed with great care, so as not to scatter the spores. Attention to this matter can but have a beneficial effect upon the prevalence of the disease.

Summer Disinfection.—In practically all parts of the State the long, dry summer period affords a very available time for the thorough disinfection of the packing-house. The mold spores can be killed by protracted drying, and it should be the practice to so thoroughly air all packing-houses during the hottest and driest part of the summer, that they will be entirely free from the fungus for the beginning of the next year's campaign. In most places this is a very easy operation, and should never be neglected where feasible.

Sulfuring.—When it is not possible to disinfect the house in the summer by drying, as suggested above, or by whitewashing, it may be possible to destroy the spores by the free use of sulfur. This is also possible during the actual packing season. The sulfur should be burned so that the fumes will come in contact with every part of the inside of the packing- or curing-house. Usually these buildings are not tight enough to permit of very thorough work, so that no prescription of the amount to use can be safely made. The material is not expensive, so that the best policy is to use it very liberally whenever the presence of the fungus in quantity is known or suspected to exist in the house.

ORCHARD PRACTICE.

A great deal of fruit undoubtedly goes into the packing-house already covered with the spores of this rot-fungus. As much carelessness in the disposal of rotten fruit is seen in the orchard as has been pointed out above as occurring about the packing-house. Rotten fruit is very commonly allowed to fall upon the ground, and is turned under with the plow, to be turned up again in subsequent cultivations. In almost any orchard in which the disease is prevalent, one would not have any difficulty in finding oranges or lemons, covered with quantities of mold-spores, lying upon or just beneath the surface of the ground, from which they may be blown over the fruit with the dust.

It is not only the Navels that are thus endangered; but these fruits are probably the only ones that commonly become rotten before they are picked. All the fruit in the orchard is liable to become affected after it is packed, as soon as the spores existing on its surface have an opportunity to germinate. It is particularly desirable, therefore, that in the orchard all decayed fruit be gathered and buried so deeply that it will not be turned up by the plow; or that it should be otherwise disposed of. This may be done by digging a deep hole every little distance in the orchard, and piling in the rotten fruit from adjacent trees. Another method would be to gather and compost decayed fruit, thus destroying the spores; in this way finally using the fruit for fertilization, as mentioned by Professor Hilgard in the paragraph below. Either method provides a safe and rapid means of disposing of the refuse fruit, which will certainly very materially decrease the amount of spores, and therefore the liability to rot.

THE FERTILIZING VALUE OF CITRUS CULLS.

In connection with the foregoing discussion of the cause and prevention of the rot of citrus fruits, it seems desirable to discuss a point very frequently mooted, viz., the fertilizing value of such culls. Since, from Professor Woodworth's investigations, it is clear that the culls are not merely useless, but a positive detriment if allowed to rot under the trees, as is commonly done, the question of their disposal raises that of their value in restoring the plant-food they have derived from the soil. It is clear that each fruit represents the ingredients which will be required to produce another in the future; and in accordance with the golden rule of returns to the soil, they should be given back. The question arises, however, as to the exact value represented, and the expense the grower can afford to go to save it, as against purchasing fertilizers in the market.

The ash-percentage of fresh citrus fruit is (in California) .43 per cent on the average. Analysis shows that of this amount about one-half is potash, while .053 per cent is phosphoric acid. Or, stated for 1,000 pounds of oranges, we have 2.11 pounds of potash, 1.25 pounds of phosphoric acid, and, besides, 1.83 pounds of nitrogen in the fresh fruit. Assigning to these ingredients their accepted commercial values for such conditions, we find the manurial value of the 1,000 pounds, aside from the humus, to be about 30 cents; it will not exceed 40 cents.

As an alternative of the deep burying recommended by Professor Woodworth in order to render the culls innocuous to the crop, I have heretofore suggested composting with lime and earth on special piles; the compost to be hauled out to the orchard after the complete decomposition of both fruit and mold-spores. Considering that the culls are usually gathered into piles anyway, this would involve little outlay beyond that for lime; and for this purpose the spent lime from the beet-sugar factories would be available, provided it were sold at its true manurial value only, which is about $2.30 per ton in the moist condition, or $3 in the dry. When fresh lime is used it will be best to employ it in the unslaked condition, so that it will help to take up the moisture from the fruit. The compost thus produced would be a substantial addition to the productiveness of the grove. But each one must judge according to his location, etc., whether this or the purchase of fertilizers would pay best. The tree roots would eventually find the pits in which the culls were buried; but to plow them in deep enough to prevent their being brought up by the plow afterward, would need the "master's eye." [E. W. H.]

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AGRICULTURAL EXPERIMENT STATION.

LANDS OF THE COLORADO DELTA IN THE SALTON BASIN.

FIELD AND LABORATORY WORK

BY FRANK J. SNOW.

DISCUSSION

BY E. W. HILGARD AND G. W. SHAW.

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LANDS OF SALTON BASIN, SOUTHERN CALIFORNIA.

The Salton Basin, in the southeastern portion of the Colorado Desert, within the State of California, is a depression about 290 feet below sea level at its lowest point, where thick saline deposits have given rise to important enterprises in mining common salt. While the northern portion of this basin is largely covered with drifting sand, surrounding many tracts that, with irrigation, produce (as at Indio) abundant and early crops, the southern portion, here being considered, is to a considerable extent covered with alluvial deposits originally derived from the Colorado River; as is clearly indicated by their nature, as well as by the fact that at times of exceptional high water (such as occurred in 1890) the river overflows into the basin through two channels, named respectively the Salton and New rivers. In the year mentioned, the overflow was so copious as to flood the salt deposits, and for nearly a year there was a lake where doubtless originally the waters of the Gulf of California received the entire flow of the Colorado. The alluvial deposits of the river finally cut off the upper end of the Gulf, so that now a large area of alluvial country, or delta, extends between the Salton Basin and the present head of the Gulf. The part of this delta which slopes toward the north into the Salton Basin forms the subject of the present discussion. The subjoined map, reduced from sheets furnished by the "Imperial Land Company," will serve to elucidate the general features of the region, a portion of which has been surveyed in sufficient detail to give the contour lines indicating the slope, which, as will be noted, is considerable enough to render both irrigation and drainage easy; in general, toward a depression designated as Mesquit Lake, which can also serve as a back-water reservoir from Salton River and the main canal. To the eye, however, most of the country appears as a level plain, except where the channels of the streams form breaks. Its natural vegetation is very scanty; mesquit is found scattered over the plains, with locally some poplars on the lower ground; also low shrubby and herbaceous, partly saline, growth. On the higher ground vegetation is generally very sparse, sometimes entirely absent over considerable tracts; locally there are areas in which certain plants are massed.

As to the thickness of these delta deposits, the only evidence as yet available is from a boring at Imperial made to determine the feasibility of obtaining artesian water in this region. This boring was carried to the depth of 685 (?) feet, without penetrating anything different from the various materials found at or near the surface, and without finding water. It is thus apparent that the Gulf was originally of very considerable depth. The level of the Salton salt deposit at the works is stated by Gannett to be 262 feet below sea level.

Successive Efforts at Investigation.—The attention of the Station Director was first called to the agricultural possibilities of this southern portion of the Colorado Desert in 1893, by a request on the part of several gentlemen who proposed to take out water from the Colorado River near Yuma, for the purpose of irrigating this region; and also proposed to fit out an expedition, properly equipped, in order that he might explore the country in question personally. Financial difficulties intervening prevented the carrying-out of the plan at that time; but a few samples of water from the lakes, and of soils superficially taken, proved that the latter were very similar to that of the immediate bottom of the Colorado River, which previous analyses had already shown to be of extraordinary intrinsic fertility.*

A similar effort was made in 1896–7 by other parties, who also supplied to the Station some soil and water samples for examination. These but corroborated the previous conclusions, with the added suggestion that a considerable proportion of alkali salts was present in soils as well as in waters; so that a thorough examination of the region in this respect was manifestly called for.

It was not until 1900, however, that the present organization, the "Imperial Land and Water Company," took active steps toward the construction of an irrigation canal, and renewed the proposition that the land should be explored under the supervision of this Station, in order to determine definitely its adaptation to general or special agriculture and horticulture. The first step was the taking of soil samples over a considerable portion of the district by an employé of the company, in substantial accordance with printed directions furnished. These samples, unfortunately, could not be very accurately located, in the absence of a regular land survey; but they furnished a fair general idea of the character of the lands, and further emphasized the necessity of a more definite and detailed examination, in order to determine what portions of the territory under the canal might or might not be considered suitable for general farming purposes.

To indicate the general idea obtained from the analysis of these twenty preliminary samples, the results have been calculated so as to show the soluble salts (alkali) to the depth of four feet, taking the average alkali content found in the soils to the depth to which each sample had been taken, and assuming that this represents approximately the saline condition for each foot.

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* See report of California Experiment Station for 1882.

NOTICE.

Attention is called to the fact that certain errors occur in Table I, page 7, of Bulletin 140 of this Station. The errors have been corrected in the following reprint, and you are requested to insert it in the proper place in the said bulletin.

TABLE I. Preliminary Results of Alkali Leachings.

Locality.	Percentages.				Pounds per Acre in 4 Feet.			
	Sulfates.	Carbonates.	Chlorids.	Total.	Sulfates.	Carbonates.	Chlorids.	Total.
1	.196	.013	.094	.303	31,360	2,080	15,040	48,480
2	.068	.010	.043	.121	10,880	1,600	6,880	19,360
3	.129	.012	.082	.223	20,640	1,920	13,120	35,680
4	.162	.007	.045	.214	25,920	1,120	7,200	34,240
5	.072	.010	.019	.101	11,520	1,600	3,040	16,160
6	.294	.008	.496	.798	47,040	1,280	79,360	127,680
7	.042	.009	.002	.053	6,720	1,440	320	8,480
8	.631	.013	.424	1.068	100,960	2,080	67,840	170,880
9	.179	.009	.162	.350	28,640	1,440	25,920	56,000
10	.207	.010	.027	.244	33,120	1,600	4,320	39,040
11	.173	.010	.056	.239	27,680	1,600	8,960	38,240
12	.172	.014	.044	.230	27,520	2,240	7,040	36,800
13	.141	.011	.164	.316	22,560	1,760	26,240	50,560
16	.142	.012	.137	.291	22,720	1,920	21,920	46,560
17	.080	.007	.035	.122	12,800	1,120	5,600	19,520
18	.056	.009	.001	.066	8,960	1,440	160	10,560
19	.129	.009	.005	.143	20,640	1,440	800	22,880
20	.152	.009	.154	.315	24,320	1,440	24,640	50,400
					484,000	29,120	318,400	831,520
Average in 4 feet					26,888	1,612	17,688	46,195
Minimum in 4 feet					6,720	1,120	160	8,480
Maximum in 4 feet					100,960	2,240	79,360	170,880

It will be observed that this preliminary examination indicates the average total alkali in the first four feet of soil to be about 1¼ per cent, or 46,000 pounds per acre; about three-eighths of which is common salt and about three-fifths glauber salt. Further, the enormous variation from 8480 to 170,880 pounds of soluble salts per acre—from a soil which will not injure citrus fruits to one that would be repugnant to all but the hardiest of alkali plants—shows that the land is quite "spotted," some localities being too highly charged with alkali to admit of any successful agricultural operations, while others do not exceed in amount the salts found in some of the better agricultural regions of the State. This condition suggested forcibly the need of a detailed local examination of the region.

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16	.142	.012	.137	.291	22,720	1,920	21,920	46,560
17	.080	.007	.035	.122	12,800	1,120	5,600	19,520
18	.056	.009	.001	.066	8,960	1,440	160	10,560
19	.129	.009	.005	.193	20,640	1,440	800	30,880
20	.152	.009	.154	.315	24,320	1,440	6,160	50,400
					575,320	29,120	248,880	853,320
Average in 4 feet					28,766	1,456	12,444	42,666
Minimum in 4 feet					6,720	1,120	160	8,280
Maximum in 4 feet					96,960	2,240	79,360	170,880

It will be observed that this preliminary examination indicates the average total alkali in the first four feet of soil to be about one per cent, or 40,000 pounds per acre; about two-sevenths of which is common salt and about two-thirds glauber salt. Further, the enormous variation from 8,280 to 170,880 pounds of soluble salts per acre—from a soil which will not injure citrus fruits to one that would be repugnant to all but the hardiest of alkali plants—shows that the land is quite "spotted," some localities being too highly charged with alkali to admit of any successful agricultural operations, while others do not exceed in amount the salts found in some of the better agricultural regions of the State. This condition suggested forcibly the need of a detailed local examination of the region.

Exploration by Mr. F. J. Snow.—The Director being unable to visit the region personally, Mr. F. J. Snow, at the time assistant in the laboratory of agricultural chemistry, was deputed to undertake the work of exploration, and the field work was carried out by him with the effective assistance and at the expense of the company, during the three weeks of Christmas vacation, 1900–1901. The examination of the numerous samples it was found necessary to collect occupied over four months of his time during 1901; and the resignation of Mr. Snow from the staff of the Station at the beginning of the session of 1901–2 unavoidably delayed the report of results until the vacancy thus created could be acceptably filled. Almost the entire laboratory work had been completed by Mr. Snow before leaving; but it was only on the arrival of Professor G. W. Shaw (January 3, 1902) that the elaboration of the report could be actively taken in hand. In view of the public interest in the subject at this time, it is thought best to issue this record and discussion of results as a bulletin, rather than as a portion of the subsequent main report for the year.

Variability of Alkali in Soils.—In considering the results of this investigation, it must be remembered that the content of alkali salts in lands varies widely even within short distances, and that it is far from certain that either a favorable or unfavorable condition is necessarily continuous over any large tract. This has been abundantly shown in the detailed surveys made of the substation tracts at Tulare and Chino; at the latter point, squares of 50 feet were laid off, and each one sampled at the center; and the differences found on adjacent squares were frequently very great. The same occurred at Tulare. It is not, therefore, easy to make an "alkali map" of any large tract that shall truly represent, in detail, the cultural possibilities where the case is critical. The "alkali spots" so commonly scattered over regions where alkali occurs, demonstrate very plainly the difficulty of mapping, with any degree of accuracy, the intensity of alkali contamination, except as a broad average. Moreover, the circulation of water in soils will often, in the course of a few years, alter materially the distribution of the salts within them, especially when under cultivation.

THE SOILS OF THE BASIN.

Classification.—The area covered by this exploration embraces about 400,000 acres. Within this there are two extreme typical classes of soil widely different from each other; one being a very hard, compact clay, which underlies apparently a large area along and east of New River, and at the time had been very largely taken up by settlers. The other is a silt, or loam soil, which, according to Mr. Snow's estimate, comprises about one fourth of the area studied by him; it lies mostly along and to the eastward of Salton River. About one hundred and twenty-five thousand acres have been taken up by prospective settlers.

PHYSICAL CHARACTERISTICS.

The clay, as seen in the banks of New River, is very hard and compact, so that it can not be crushed by the hand and is even scratched with difficulty. It wets very slowly, and when water-soaked it shows, when worked on the hand, a total absence of any sensible grains of sand or silt, and becomes extremely plastic and adhesive. It is evidently a back-water deposit, and can not by any practicable means become an acceptable soil.

The silt soil, which represents deposits formed by flowing water, contains a considerable proportion of fairly coarse sand in addition to the finer kinds of silt, and only enough clay to render it somewhat plastic and adhesive on kneading with water. It ranks as a medium heavy and sometimes light loam, and wets very readily.

Between these two extremes there are, of course, many grades of transition, such as compacted silt and friable clay, which in themselves are excellent soil materials. In general, when the dry clayey material can be crushed between the palms of the hands, or made to crumble quickly by wetting, the physical constitution of the soil will not stand in the way of its successful cultivation, provided unsuitable materials do not underlie it within a few feet.

The detailed physical analyses of these typical samples gave the following results:

No. 2325. *Silt soil* from the east side of Salton River, 2½ miles north of East Side camp, Sec. 25, T. 13 S., R. 14 E.

No. 2324. *Clay soil* from the east side of New River, 3 miles northwest of East Side camp, Sec. 28, T. 13 S., R. 14 E.

No. 2326. *Silt soil* from the west side of New River, 11 miles northwest of East Side camp, Sec. 31, T. 12 S., R. 13 E.

No. 2327. *Clay soil* from 1 mile east of Imperial.

No. 1197. *Bottom soil* from Gila River, near Yuma. This analysis of this sample was given in the report for 1891–2.

No. 506. *Bottom soil* of Colorado River. This analysis was given in the report for 1892–4.

TABLE II. Physical Analyses of Salton Basin Soils.

Hydraulic Value (Velocity Per Second).	Diameter of Grains.	Character of Material.	Silt Soils.			Clay Soils.		Bottom Soil.
			†Special Typical Sample. No. 2325.	Locality No. 5. First Foot. T. 12 S., R. 13 E., Sec. 33. No. 2326	*Bottom Land, Gila River, near Yuma. No. 1197.	†Special Typical Sample. No. 2324.	Locality No. 15. First Foot. T. 15 S., R. 14 E., Sec. 16. No. 2327.	‡Colorado River, California. No. 506.
64 mm.	.50 to .30 mm.	Very coarse sand	} .49 (Very coarse, Coarse and Medium sand)	.13	.28	} .94 (Very coarse, Coarse and Medium sand)	.21	.13
64 to 32 mm.	.30 to .16 mm.	Coarse sand		.27	2.79		.34	.15
32 to 16 mm.	.16 to .12 mm.	Medium sand		1.63	22.00		1.48	.11
16 to 8 mm.	.12 to .072 mm.	Fine sand	5.19	13.64	33.97	.46	1.45	.75
8 to 4 mm.	.072 to .047 mm.	Very coarse silt	26.08	27.58	33.01	1.68	2.75	2.51
4 to 2 mm.	.047 to .036 mm.	Coarse silt	23.50	20.52	10.17	1.73	6.25	8.38
2 to 1 mm.	.036 to .025 mm.	Medium silt	13.32	9.61	3.21	1.31	8.81	12.64
1 to .5 mm.	.025 to .016 mm.	Medium silt	.61	2.42	2.04	.25	8.54	11.28
.5 to <.25 mm.	.016 ?	Fine silt	15.34	13.16	5.53	63.31	48.92	.79
<.25 to .0023 mm.		Colloidal clay	14.80	9.74	3.21	28.78	18.58	54.97
		Totals	99.63	98.70	94.22	96.46	97.32	91.71

* Report of California Experiment Station, 1891-2, p. 45.

† NOTE.—These special samples were selected as being very typical of the class represented. Each consisted of about 50 pounds of soil taken to a depth of 4 feet, thoroughly mixed and reduced to convenient bulk by quartering. These samples were used by Mr. Snow for both the percolation, capillary, and other experiments, as well as for the complete chemical and mechanical analyses.

‡ Report of California Experiment Station, 1892-4, p. 70.

An examination of this table shows that the silt soil contains about 60 per cent of silt of medium to coarse grade, which imparts the distinctive character to the soil. It also carries from 10 to 15 per cent of very fine silt, which in some respects might act similarly to clay in respect to capillary power. The soil characterized as clay carries about 30 per cent of clay proper, and over 60 per cent of very fine silt; making over 90 per cent of extremely fine matter, which, when compacted (as much of it is), makes a material almost impervious to water. The truth of this latter statement is well illustrated by the results obtained in the percolation experiments (diagram I); and it is obvious that a material of this character can not be considered suitable for irrigation culture, or, in fact, for any of the usual crops under any practically possible treatment. It is too "fat" even for potter's clay, for which its high plasticity would otherwise render it suitable.

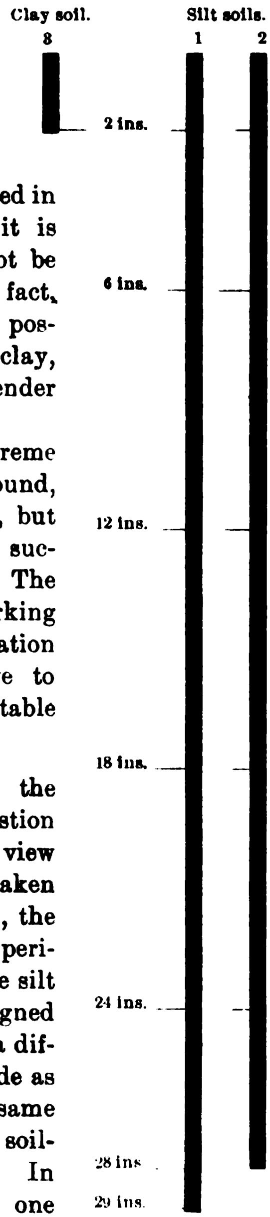


DIAGRAM I. Rate of percolation in 12 hours.

As is natural, intermixtures of these two extreme materials in various proportions are frequently found, often in shaly masses resembling the hard clay, but softening readily in water and quite capable of successful cultivation if freed from excess of alkali. The "hand test," by wetting with water and working between the palms of the hands, and the observation of their percolative power, will generally serve to distinguish these shaly clay-loams from the intractable hard clay of the New River banks.

Percolation of Water.—In irrigated regions the rapidity with which soils can be wetted is a question of prime importance to the farmer; and with a view of ascertaining the rate at which water will be taken by each of the two types of soils here discussed, the following experiments were undertaken. Experiments No. 1 and No. 2 were conducted with the silt soil, and No. 3 with the clay soil. No. 2 was designed as a check upon No. 1, and was conducted at a different time; but all essential conditions were made as similar as possible. In each experiment the same constant depth of water was maintained over the soil-column by means of a Marriotte apparatus. In experiment No. 1 the tube used was one and one half inches in diameter and thirty-eight inches in length, and contained 1,700 grams of soil. In experiment No. 2 the diameter of the tube was two inches, and the length thirty-two inches, the weight of the soil being 1,400 grams. In each case the soil was well settled in the tube. Experiment No. 1 was begun at 6:20 A. M., April 15th, and ended at 11:25 P. M. of the same day. Experiment No. 2 was begun at 5:20 A. M., May 2d, and ended at 9:14 P. M. of the same day. The rate of wetting is graphically presented in the accompanying exhibits (diagram I), in which the depth reached in twelve hours is shown.

Practical Deductions.—In soils as strong in alkali as these samples, the rate of wetting becomes even a more important factor for consideration than in non-alkali regions. Wherever the upper layers of the soil are highly charged with the salts, the first thing needful to be done—aside from thorough underdrainage—is that of heavy irrigation by flooding, in order to wash the excess of alkali from the upper layers to the lower, and thus reduce the amount in the upper four to six feet of soil below the limit of endurance for the various crops. (For a discussion of the "Tolerance of Alkali by Certain Cultures," the reader is referred to Bulletin No. 133 of this Station.) If an excessive amount of water has to be used in order to accomplish this washing-down, or if the water has to be kept upon the ground an undue length of time, there is the constant attendant danger of "swamping" the soil, and thus putting it out of good physical condition; and again, in a soil in which the lime carbonate runs as high as seems to be the case in these soils, there is the further danger of the development of black alkali, thus adding to the already serious condition of many of the sampled areas. If, however, the soil be of such a nature as to preclude the possibility of wetting it thoroughly to a depth of five or six feet within a reasonable length of time under irrigating conditions, then if it be placed under cultivation, there may be expected a considerable increase of alkali near the surface during the first three or four years.

Comparing these two soils it was found that under these experiments the silt soil became wet to the depth of three feet within 18 hours, while in the case of the clay soil it required 165 days for the water to reach the same depth; a rate entirely prohibitive of successfully handling this soil under its highly saline conditions. Further, the experiment indicates that this clay soil is so slow in taking moisture from above that in a period of ten days it would only become wet to a depth of seven inches, a rate too slow for agricultural operations.

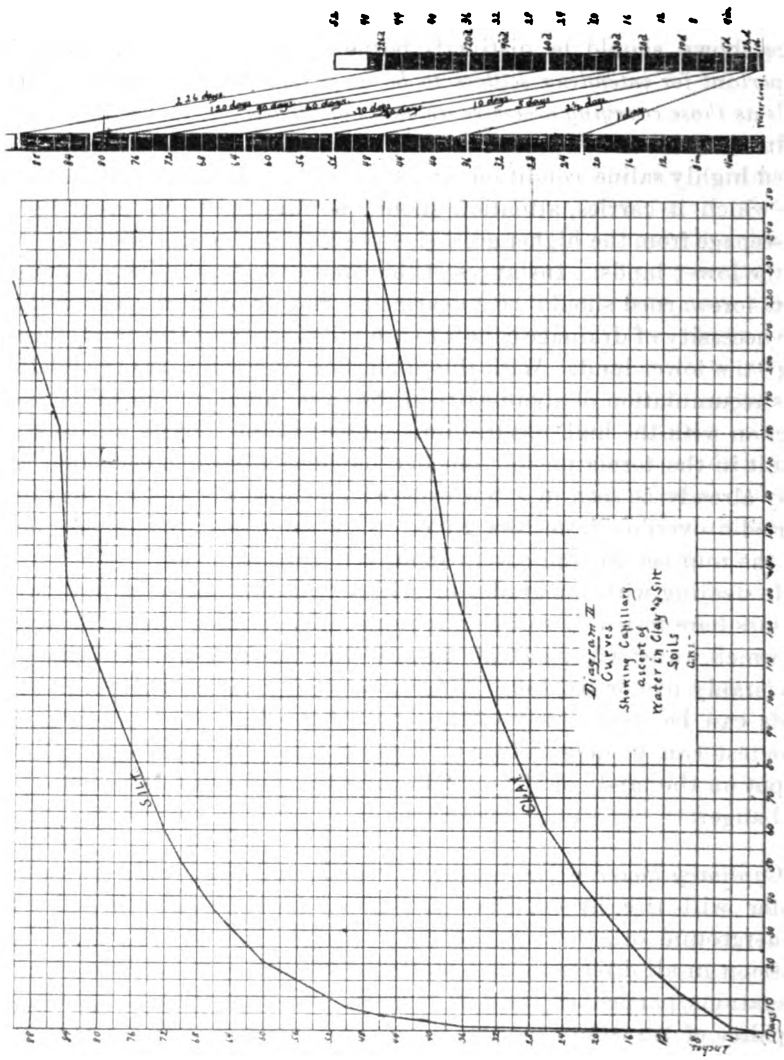
In the silt soil, the conditions for successful treatment under irrigation are much more favorable. Carrying, as it does, a heavy amount of alkali within the first three feet, the same method of heavy flooding and subsequent deep-furrow irrigation would have to be resorted to; and a study of the data shows that if the water will carry a considerable portion of the salts to a depth of four or five feet within a reasonable time, the conditions may be considered as favorable as in many other well-cultivated portions of the arid regions. The experiments show that this may be accomplished within a period of 18 to 36 hours, a time perfectly compatible with agricultural practice. The particular thing here shown should be distinctly borne in mind; namely, *that it is as important for intending settlers to be as careful to avoid the compact clay soils as those carrying excessive amounts of alkali.*

In connection with the silt soil, in view of its looseness of texture, its often highly saline condition, and the heavy percentage of lime carbonate which it carries, attention should be directed to the great liability to seepage from the higher ground, especially where near the main canal, to the lower lands. Instances of this are so common in irrigated regions that forewarned should be forearmed. Sooner or later there will arise the necessity of drainage canals to keep the seepage water from "swamping" the lower land. With this underflow of water there is a greater or less accumulation of alkali salts in the lower areas, which, taken in connection with the high natural lime content of the soils, is almost sure to result in the formation of considerable black alkali; a condition which may already be seen in a few isolated localties where there has been a periodic overflow from New River. One such is indicated on the map by the number 25, and covers about 200 acres.

In dealing with the grades of soil intermediate between the two extremes here tested, it will be advisable to determine *first of all* the rate at which water will penetrate them to the depth of not less than four, preferably five or six, feet. This will at once indicate whether the alkali salts can be successfully leached out of the land on a practical scale. The test can be made either by digging a pit, alongside of which water is put on the land; or else by following the water down by means of the soil auger.

Capillary Power.—The height to which, and the rapidity with which water will rise by capillary movement (wick action) in soils from underground or sub-irrigation water, and the ease of its general transmission in all directions, is a matter of vital importance in agricultural operations, particularly in arid regions. While both the height and the rapidity of transmission are to a large degree dependent upon the physical nature of the soils, yet it is reasonably certain that there are certain chemical factors involved as well. Inasmuch as this capillary power is dependent upon the size of the spaces between the particles constituting the soil, varying inversely as this space, capillary ascent is less in sandy than in clay soils. In the former the rise is more *rapid*, since there is less frictional resistance to the motion of the water; but there is, also, much less surface tension, and while the rise is rapid the water may not ascend more than a few inches.

As between silts and clays, such as we have to deal with in this discussion, the conditions are quite different and merit some attention,



particularly as these silt soils are so prevalent in the arid regions. The soils used in this experiment were from the same lot as those used in the percolation experiments and in the complete chemical and mechanical analyses described above. The soils were tapped into the tubes, which were then placed upon a perforated support in a water reservoir.

The results are shown graphically by means of both curves and vertical columns. In the case of the curves, the verticals represent equal heights in inches; the horizontals show the length of time in days. In the columns, to facilitate comparison, the points reached in each at the end of the several periods of time are connected by lines.

The particular point to attract attention in comparing these two soils is the great difference in the rapidity of the rise of water. In the case of the silt soil, in seven minutes it had ascended 2 inches, in eighteen minutes 4 inches, in one hour 7 inches, in one hour and forty-three minutes 10 inches; while it took the clay eleven hours and seventeen minutes to draw the water to a like height, or approximately ten times as long. This rate, however, diminishes somewhat more rapidly in the silt as the water column ascends, than it does in the clay. This rapid rise of water in soils of a somewhat similar character was noticed some years ago, and commented upon in the annual report of this Station for 1894. In the case of the alluvial soil from Gila River, near Yuma, the water rose 9½ inches in one hour; at the end of twelve hours it had reached a height of 24 inches, and at the end of the first day it had reached the height of 27½ inches; while the silt soil here under consideration reached the height of 30 inches in a like time. The clay soil of the region must be looked upon, then, as very slow in its capillary action when compared with the lighter alluvial silt, the ratio for the first few hours being about 1:10.

CHEMICAL COMPOSITION OF THE SOILS.

In a previous report* of this Station, analyses of three samples of soil from this region are given, and in the discussion of the results it was stated: "It will be noted, as a common factor of these three soils, that they are highly calcareous; they show the presence of the carbonate of lime by effervescence with acids. The Colorado River soil is very rich in potash; the Gila soil much less so, yet very adequately supplied; the amount of soda found does not indicate much alkali contamination. The Colorado soil has a good, but not high, supply of phosphoric acid; the Gila soils both show an unusually high percentage of that ingredient. The Colorado soil has a good supply of humus; the Gila soil is notably deficient therein for a bottom soil."

A complete chemical analysis of each of the types here under consideration was made by Mr. Snow, and the subjoined results obtained. The analysis of other soils from the same region, the discussion of which appears above, is included for the sake of comparison.

* Report of California Experiment Station, 1890, p. 50.

TABLE III. Analyses of Colorado Alluvial Soils.

	Clay Soil. No. 2824.	Silt Soil. No. 2825.	Colorado River, California, Bottom Soil. No. 506.	Gila River, Arizona, Bottom Soil. No. 1196.	Gila River, Arizona, Bottom Subsoil. No. 1197.
Coarse materials > 0.5mm	....	....	....	....	....
Fine earth	100.00	100.00	100.00	100.00	100.00
Analysis of Fine Earth.					
Insoluble matter	38.65	62.67	58.57	57.90	64.83
Soluble silica	15.79	10.93	5.33	13.49	11.85
Potash (K_2O)	.76	.74	1.18	.66	.67
Soda (Na_2O)	.34	.29	.16	.25	.39
Lime (CaO)	4.35	3.75	8.67	6.26	4.33
Magnesia (MgO)	1.24	1.68	2.97	.66	1.97
Br. ox. of manganese (Mn_3O_4)	.10	.01	.03	.08	.03
Peroxid of iron (Fe_2O_3)	6.15	3.71	4.14	5.57	6.27
Alumina (Al_2O_3)	10.52	4.26	8.38	7.48	4.27
Phosphoric acid (P_2O_5)	.23	.22	.13	.23	.17
Sulfuric acid (SO_3)	.49	.36	.15	.03	.05
Carbonic acid (CO_2)	5.30	2.32	7.82	2.63	3.56
Water and organic matter	15.84	8.93	3.34	4.98	1.14
Total	99.76	99.87	100.87	100.22	99.83
Humus	.38	.65	.75	.38	....
" Ash	1.01	.69	1.15	.43	....
" Nitrogen, per cent in humus	18.42	10.92	....	....	....
" Nitrogen, per cent in soil	.07	.07	....	....	....
Available phosphoric acid (citric acid method)	.012	.01	....	....	....
Hygroscopic moisture (absorbed at 15° C.)	5.75	2.98	9.26	4.91	3.48
Water-holding power	74.39	46.26	48.40	....	42.30

Intrinsic Fertility of these Soils.—In a general review of these soils, one is impressed at first by the general similarity in composition, bearing out the statements made several years ago and quoted above, viz: that the intrinsic fertility of the soils of this region is high. The lime content of all three is high; and the fact that this lime is present largely in the form of a carbonate, as indicated by the high per cent of carbonic dioxid, also indicates a high general availability of the other critical elements. In the case of the clay it will be noted that there is a much larger portion of soluble matter than in the silt, which is further shown by its higher alkali content, discussed later in this bulletin. In this latter respect both the silt and soil No. 506 have the advantage of the clay. This fact is also borne out by the higher per cent of both soda and sulfuric acid present in the clay when compared with the other soils. There is about two thirds as much soluble silica in the silt as in the clay. As to potash, all three soils are very rich, there being nearly four times as much as the average for soils of humid regions. In this respect the soils must be considered as permanently fertile. On the side of phosphoric acid there is little difference in the two types, both having an excellent supply, exceeding that of soil No. 506 quite materially; still, the latter could not be considered deficient. The humus content is good—better in the silt than in the clay—especially as the nitrogen content of the humus is high. The water-holding power is greater by 30 per cent in the case of the clay than in the silt, which might be expected on account of the difference in the nature of the two soils. All three of these soils must thus be ranked as exceptionally good in their supplies of plant food.

THE SOLUBLE SALTS IN THE SOIL.

Importance of the Alkali Factor in Arid Regions.—In the selection ot lands in arid regions it is highly essential that more than the physical nature and general fertility of the soils be considered. There are factors entering into the soil problems of such regions which are entirely foreign to those of humid climates, and which, in many cases, are far more complicated. A soil may possess all the elements, both physical and chemical, of intrinsic fertility, and still be entirely unsuited to agricultural operations under irrigated conditions; points which, in a humid region, might be considered very favorable to a soil may, under irrigation, if the alkali condition of the undersoil be not accurately known, cause the ruin of the land. Being unaware of these essential differences, settlers from the humid region are not infrequently led to select land which is, or may become, entirely unsuited to any kind of crop-growing. It is important, then, that the truth should be placed before them in these matters, not only that *they* may avoid financial loss, but also that the evil results sure to follow such unwise selections may not cast reflections upon the State. On the other hand, it is not at all uncommon for people temporarily residing in arid regions to make broad and sweeping condemnations of lands which experience and a thorough understanding of arid conditions will not bear out.

Alkali lands, when at all adapted to agriculture, are intrinsically of the very richest character; and may, as a rule, be considered as exceptionally fertile upon the mineral side when compared with the humid-region soils. In order to realize these advantages, however, care is needed in handling such lands, and ignorance of the true condition may cause very serious financial loss, both to the individual and to the State. A notable case is that of the Fresno plateau region—the divide between the San Joaquin and Kings rivers—where there were no signs of alkali when the region was settled and for some time thereafter. Gradually small spots of alkali appeared in the older settlements, enlarging from year to year as the point of tolerance was passed for the several crops, finally causing the death of vines and trees to such an extent as to attract serious attention. It has only required a thorough understanding of the conditions to point out an application of the rational treatment of drainage, combined with the use of gypsum, when needed, as a remedy for a trouble that threatened to overrun the country.

The alkali factor should always, therefore, receive careful attention as to both surface and undersoil conditions. Three points demand consideration in this connection, viz:

1. The soluble salt content of the soil itself;
2. The salt content of the available irrigation water;
3. The condition of the surface and sub-drainage in connection with the nature of the soil.

The Nature of Alkali.—The nature and kinds of alkali have been repeatedly treated of in the several publications of this Station, but it is deemed best to again state here that, "broadly speaking, it may be said that, the world over, alkali salts usually consist of three chief ingredients, namely, *common salt*, *glauber salt* (sulfate of soda), and *salsoda* or *carbonate of soda*. The latter causes what is popularly known as "black alkali," from the black spots or puddles seen on the surface of lands tainted with it, owing to the dissolution of the soil humus; while the other salts, often together with epsom salt, constitute "white alkali," which is known to be very much milder in its effect on plants than the black. In most cases all three are present, and all may be considered as practically valueless or noxious to plant growth. With them, however, there are almost always associated, in varying amounts, sulfate of potash, phosphate of soda, and nitrate of soda, representing the three elements—potassium, phosphorus, and nitrogen—upon the presence of which in the soil, in available form, the welfare of our crops so essentially depends, and which we aim to supply in fertilizers. The potash salt is usually present to the extent of from 5 to 20 per cent of the total salts; phosphate, from a fraction to as much as 4 per cent; the nitrate, from a fraction to as much as 20 per cent. In black alkali the nitrate is usually low, the phosphate high; in the white, the reverse is true." *

With regard to the relative injuriousness of the component salts it may be said that the glauber salt, *unless present in excessive amounts*, is comparatively innocuous and need not be considered a serious barrier to agricultural operations when conducted in a rational manner. The carbonate of soda, constituting the active ingredient in the so-called "black alkali," exerts a corrosive action on the root crown of the plant, and in many cases, especially in heavy soils, tends to destroy their tilth. But by the use of gypsum, it can readily be converted into the relatively innocuous sulfate. Experience on our substation tracts, as well as elsewhere, shows that any considerable amount of sodium chlorid (common salt) is fully as much to be feared as the more corrosive carbonate, since it can not be neutralized or changed within the soil, but must be bodily removed by drainage.

* Bulletin No. 128, California Experiment Station, p. 13.

ALKALI SALTS IN THE SALTON BASIN.

In considering only the *amounts* of alkali salts in the soils of this region, we find the outlook not altogether encouraging. While there is some land not too strongly impregnated to produce even now, without any special precautions, good crops of cereals, especially barley, also alfalfa, and some of the hardier orchard and small fruits, there is a very large proportion of the lands so strongly charged that, without due care, crops could be secured only for two or three years, and in some, none at all. As to *quality*, however, it is notable that there is in the great majority of cases a great predominance of the relatively innocuous sulfates—glauber salt, epsom salt, and throughout, a certain proportion of potash sulfate also, ranging in the determinations thus far made from two to over ten per cent of the total salts. Carbonate of soda is quite subordinate, because of the presence of gypsum throughout the materials. Common salt is rather abundant near the surface, but only in small supply below the first three feet, until a depth of twenty feet is reached, as is shown in the sections given below. Nitrates appear to be present throughout, to an extent varying from 1,000 to 1,800 pounds per acre (.025 to .044 per cent) in four feet depth; increasing from the surface downward, contrary to the usual rule. The alkali is, therefore, generally speaking, of the mildest "white" type, and it is not surprising that, as the crop reports given below show, seed germinates and a luxuriant growth of weeds is found even where the alkali salts are bodily blooming out along the ditches. It would thus seem that, on the whole, the hard clay is a more serious obstacle to the utilization of these extremely rich lands than are the alkali salts, so far at least as the lighter and more pervious soil qualities are concerned.

Sections of New River and Salton River Banks.—Below will be found tables and diagrams showing the results of analyses of samples taken in vertical sections from the banks of both the Salton and New rivers. These samples were taken, as indicated in the tables, to the depth of 22 feet 9 inches, and 22 feet respectively, the banks in each case having been dug away for 20 feet horizontally in order to get truly representative samples, avoiding the effects of concentration of salts by evaporation. These sections are of especial importance as indicating the general disposition of the soluble salts in the substrata of the valley; they consequently elucidate best the chances of getting rid of alkali by drainage, or by leaching downward on the land itself. The tables show the data obtained from the two stream banks, the nature of the materials being given alongside of the same.

TABLE IV. Section from New River Bank: 22 Feet, Locality No. 33.

Percentages.				Physical Characteristics of Each Thickness.		Pounds per Acre.			
Sulfates	Carbonates	Chlorids	Total			Sulfates	Carbonates	Chlorids	Total
.916	.008	.092	1.016	8 in.	Surface compacted clay; crumbles easily.	24,427	213	2,653	27,293
1.321	.010	.265	1.596	12 in.	Compacted clay; crumbles easily.	52,840	400	10,600	63,840
1.164	.008	.096	1.268	12 in.	Very tough clay; will not break nor crumble.	46,560	320	3,840	50,720
.736	.016	.060	.812	4 in.	Very hard; breaks in cakes	9,813	214	800	10,827
.556	.016	.037	.609	12 in.	Compacted, but not as hard	22,240	640	1,480	24,360
.572	.012	.032	.616	12 in.	Very hard; breaks in cakes	22,880	480	1,280	24,640
.593	.007	.036	.636	12 in.	Very hard; breaks in cakes	23,720	280	1,440	25,440
.286	.007	.249	.542	12 in.	In large chunks; very hard	11,440	240	9,960	21,680
.371	.013	.018	.402	12 in.	Not as hard; more silt; mixed	14,840	520	720	16,000
.376	.010	.014	.400	6 in.	Not as hard; more silt; mixed	7,520	200	280	8,000
.631	.012	.076	.719	12 in.	Hard compact clay; caked in chunks.	25,240	480	3,040	28,760
.661	.013	.016	.690	12 in.	Hard compact clay; caked in chunks.	26,440	520	640	27,600
.522	.013	.029	.564	12 in.	Compact; some silt	20,880	520	1,160	22,560
.584	.009	.011	.604	12 in.	Compact; more silt	23,360	360	440	24,160
.572	.014	.078	.604	6 in.	Compact; more silt	10,240	280	1,560	12,080
.258	.007	.015	.280	12 in.	Loose silt and sand	10,320	280	600	11,200
.232	.008	.025	.265	12 in.	Loose silt and sand	9,280	320	1,000	10,600
.195	.008	.021	.224	12 in.	Loose silt and sand	7,800	320	840	8,960
.257	.007	.003	.267	12 in.	Loose silt and sand	10,280	280	120	10,680
1.188	.010	.006	1.204	12 in.	Very compact	47,520	400	240	48,160
1.130	.008	.068	1.206	12 in.	Very compact	45,200	320	2,720	48,240
1.244	.012	.026	1.282	12 in.	Very compact	49,760	480	1,040	51,280
1.143	.005	.036	1.184	12 in.	Very compact	45,720	200	1,440	47,360
1.162	.007	.063	1.232	12 in.	Very compact	46,480	280	2,540	49,280

Sand and water at 22 feet.

TABLE V. Section from Salton River Bank: 22 Feet 9 Inches, Locality No. 34.

Sulfates	Carbonates	Chlorids	Total		Physical Characteristics	Sulfates	Carbonates	Chlorids	Total
.195	.007	.080	.282	12 in.	Silty; some clay somewhat compacted.	7,800	280	3,200	11,280
.603	.012	.329	.944	12 in.	Similar to above, but more compact.	24,120	480	13,160	37,760
.356	.008	.038	.402	6 in.	Like first foot	7,120	160	760	8,040
.233	.008	.025	.266	12 in.	Like first foot	9,320	320	1,000	10,640
.095	.007	.006	.107	12 in.	Like first foot	3,800	270	240	4,280
.181	.008	.013	.202	12 in.	Very loose, silty soil; a little sand.	7,240	320	520	8,080
.129	.011	.003	.143	12 in.	Very loose, silty soil; a little sand.	5,160	440	120	5,720
.121	.009	.009	.143	6 in.	Silt; some clay; slightly compact.	2,420	180	180	2,860
.164	.010	.012	.186	12 in.	Silt; compact breaks to silt soil.	6,560	400	480	7,440
.225	.008	.003	.236	12 in.	Silt; some clay	9,000	320	120	9,440
.260	.005	.007	.272	12 in.	Silt; some clay somewhat compacted.	10,400	200	280	10,880
.467	.007	.009	.483	3 in.	Silt; some clay somewhat compacted.	4,670	70	90	4,830
.331	.009	.028	.368	12 in.	Silt; some clay somewhat compacted.	13,240	360	1,120	14,720
.417	.009	.026	.452	12 in.	Silt; very loose	16,680	360	1,040	18,080
.207	.008	.011	.226	12 in.	Silt; very loose	8,280	320	440	9,040
.315	.012	.015	.342	12 in.	Silt; very loose	12,600	480	600	13,680
.998	.008	.012	1.018	6 in.	Clay; compact	19,960	160	240	20,360
.372	.008	.006	.386	12 in.	Silt; some clay	14,880	320	240	15,440
.193	.014	.074	.281	12 in.	Silt; some clay	7,720	560	2,960	11,240
.292	.020	.044	.356	12 in.	Silt; lumps crumble easily	11,680	800	1,760	14,240
.132	.008	.008	.148	12 in.	Silt; very fine	5,380	320	320	5,290
.092	.010	.089	.191	12 in.	Silt; very fine	3,680	400	3,560	7,640
.416	.008	.168	.592	12 in.	Clay; compact	16,640	320	6,720	23,680
.686	.009	.285	.980	12 in.	Clay; compact	27,440	360	11,400	39,200
.771	.010	.739	1.520	12 in.	Clay; compact	30,840	400	29,560	60,800

TABLE VI. Showing Summary of Soluble Salts in the River Sections.
(Pounds per acre.)

	SALTON RIVER SILT.				NEW RIVER CLAY.			
	Sulfates.	Carbonates.	Chlorids.	Total.	Sulfates.	Carbonates.	Chlorids.	Total.
	For Total Depth: 22 ft. 9 in.				For Total Depth: 22 ft.			
Total	281,864	7,348	73,590	362,802	663,806	8,580	52,402	722,788
Average per foot	12,812	334	3,345	16,491	30,173	390	2,291	32,854
Min. in any foot	3,680	200	120	4,280	7,800	200	120	8,960
Max. in any foot	30,840	800	29,560	60,800	50,780	640	10,600	63,840
	For First 4 Feet.				For First 4 Feet.			
Total	50,044	1,376	18,240	69,660	155,888	1,788	13,372	177,040
Average per foot	12,511	344	4,560	17,415	38,972	447	5,343	44,260
Min. in any foot	6,560	295	620	7,460	22,240	346	1,480	24,360
Max. in any foot	24,120	480	13,160	37,160	50,780	640	8,347	59,133
	For the Next 6 Feet.				For the Next 4 Feet.			
Total	42,678	1,992	1,818	46,560	109,320	2,340	20,070	131,760
Average per foot	7,113	332	303	7,760	18,225	390	3,345	21,960
Min. in any foot	5,000	295	120	5,720	11,440	280	720	16,000
Max. in any foot	10,400	400	480	10,880	23,720	520	9,960	25,440

In comparing the column of total salts, it is at once apparent that the New River materials are much more heavily charged with salts than are those on Salton River. Looking closer at the nature of these materials, we find, moreover, that while the Salton profile shows mostly silts and sands, which make an easily worked loam soil, the material of the New River bank is prevalently a very close-grained, fine clay, which is practically impervious to water, as shown in the percolation experiment previously recorded. (See p. 11.) In the Salton profile we also find occasional layers of this clay; and inspection shows that in nearly all cases *this clay is more heavily charged with salts than is the silt* and sand. Thus this clay, which wets with great difficulty and when wet becomes extremely tough and plastic, is a very unwelcome soil ingredient, as it is incapable of tillage and will be penetrated only by such hardy roots as those of the mesquit and greasewood, and possibly by those of the saltbushes. It is quite unlikely that other useful trees will be able to force their roots through this uncanny material, and settlers will quite early find from experience what is quite evident from these experiments: that these clay lands are ill adapted to agricultural operations, even where a few feet of silt forms the surface.

There are, as stated, many grades of transition between this pure, tough clay and the silt, which is eminently suitable as a soil material, and when mixed with a moderate amount of the clay forms excellent

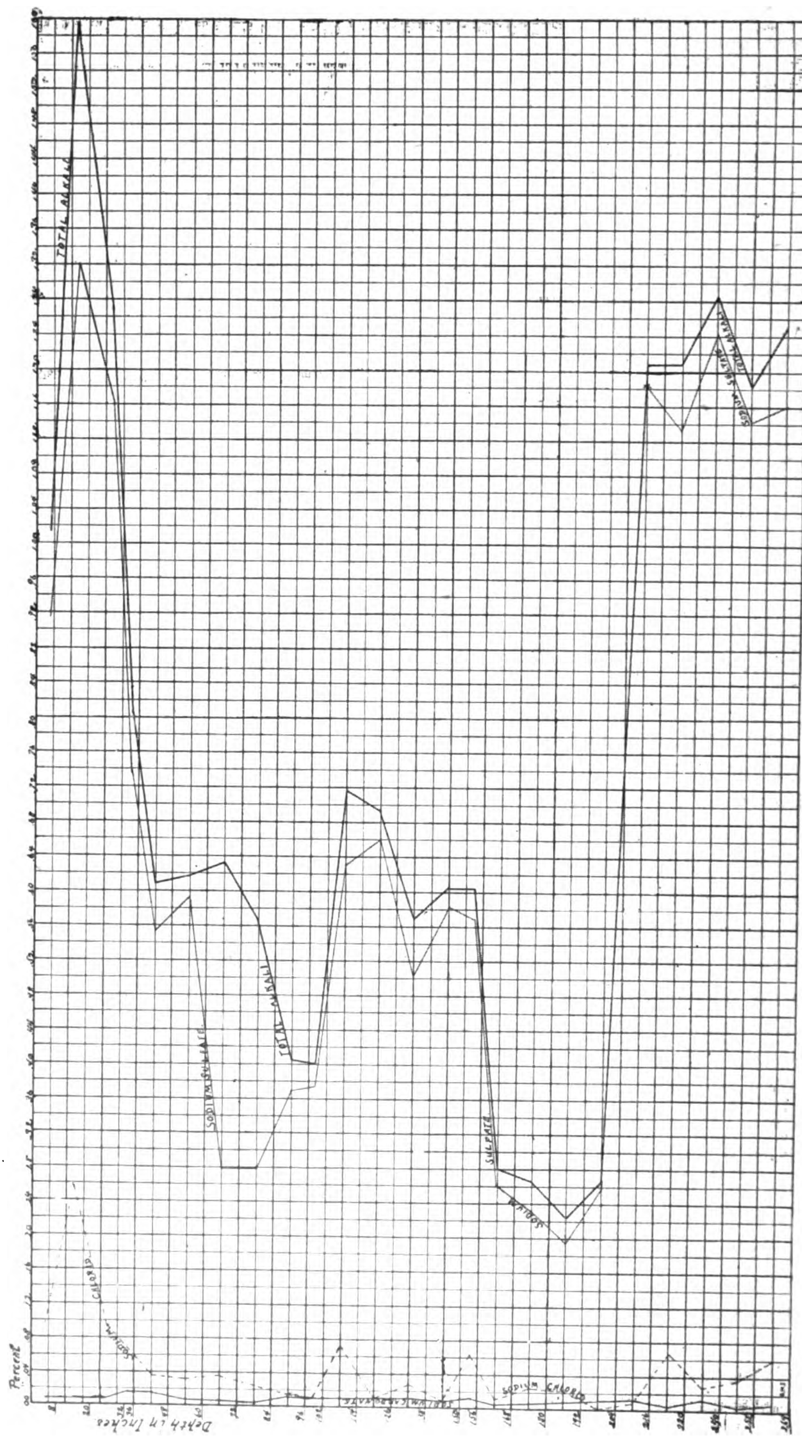


DIAGRAM III. Graphic illustration of distribution of alkali salts in New River section. See Table IV.

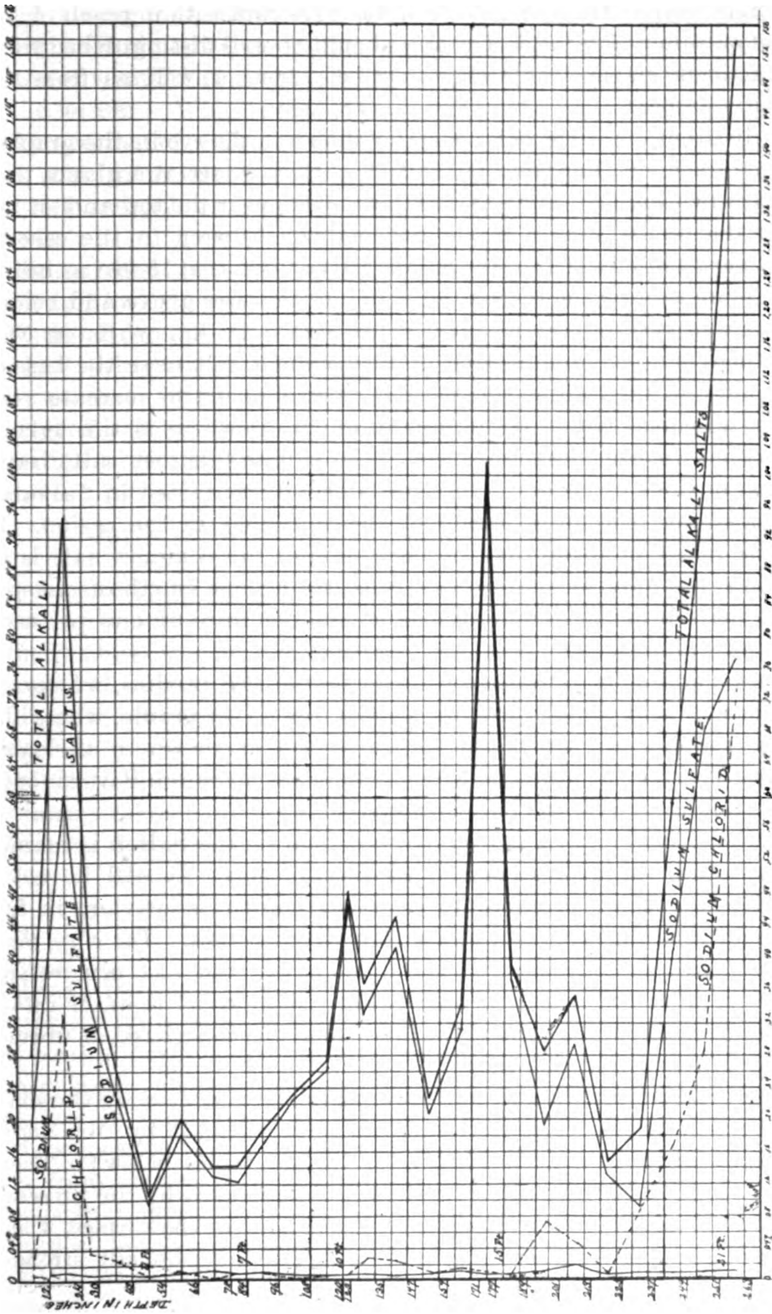


DIAGRAM IV. Graphic illustration of distribution of salts in Salton River section. See Table V.

loams or clayey soils. Such soils sometimes constitute the surface soil itself, more frequently form layers of the substrata within reach of the roots of culture plants, and of course should be well distinguished from the practically impenetrable clay described above, as well as from the loose silts proper.

The distribution of the salts is better shown to the eye in the graphic form, as given on diagrams III and IV. Here we see at a glance that there are two high maxima of total salts, viz: near the top and at the base of the profile, with a minor one midway between in the case of New River; while in that of the Salton River there is at 15 feet as heavy a maximum as near the surface, with minor increases above and below. Another and very important point of difference is that while on New River there is no notable increase of the common salt near the base of the profile, on the Salton the sodium chlorid seems to increase very materially, almost equaling the sulfate, which elsewhere is throughout the sections in considerable excess. The sulfate (glauber salt) being the least noxious by far of the three salts usually contained in "alkali," this is a strong redeeming feature of the conditions in the region. It must be noted, however, that in both profiles the common salt is in quite heavy supply *near the surface*, constituting one fourth of one per cent of the soil in the New River banks, and one third of one per cent in that of Salton River.

Comparing the total content of salts in the two profiles, we see at once that it is by far the heavier in the New River profile, where the average content per acre of the entire section, as shown in the table on pages 20–21, is 32,854 pounds; while the same on Salton River is only 16,491 pounds, or just one half as much.

The New River section is mainly clay; that on the Salton is mainly silt and sand, but with an occasional sheet of clay. It will be noted that wherever such a sheet occurs, the alkali content is heavier; in full agreement with the same fact at the New River section. *The clay, then, must be regarded not only as an obstacle to tillage and root penetration, but also as a prolific source of alkali salts. Wherever it is at, or within less than three feet of the surface,* the land should be considered as unsuitable for cultivation at this time.

The conclusion as to alkali content is again corroborated by the shallower sections from which soil samples were collected by Mr. Snow; thus, in localities Nos. 3, 6, 14, 15, 16, 17 (see tables below). There is also a decided increase wherever the silt is compacted by the presence of considerable clay. In a few cases only, mostly near the surface, where one would naturally expect an accumulation, is the loose silt strongly impregnated with salts.

Again, in comparing these two river-bank sections in respect to the upper four feet of soil, it is found that the same fact, *i. e.* that the clay is the stronger in alkali, still holds good, for the average is about two and a half times higher in the case of the New River clay than in the Salton silt, and the minimum in the latter is 4,280, against twice as much in the former. What is true of the average of the total salts is also true of the average of each ingredient; and it is still further interesting to note that in general *the same fact holds for the next four feet*, which includes a depth as great as need be considered in any agricultural practice.

Disregarding the hard clay as being unsuitable for agricultural operations, and looking more closely at the silt, it will be seen that in the six feet underlying the upper four the average of the total salts is less than one half as high as in the latter; thus indicating that the proper treatment of these lands will be that of heavy flooding for reducing the amount of salts in the upper layers of the soil, followed by deep-furrow irrigation until leaching by underdrainage shall become practically feasible.

SOILS OF THE GENERAL SURFACE OF THE BASIN.

Besides the profiles on the banks of the two rivers, soil samples were taken in the open country, with a view to making them representative of the various districts, so far as time permitted. In so doing, the several layers of materials encountered in boring were taken separately, generally to the depth of six feet when conditions permitted; and a specimen of each layer was preserved for analysis. The general aspect and "lay" of the land were recorded, and the vegetation, if any, noted and specimens thereof preserved for subsequent identification, as possible indicators of the strength and character of the alkali salts.

PHYSIOGRAPHIC FEATURES.

(By Mr. Snow.)

"Localities Nos. 1, 5, 6, 7, 17, 18, 19, and 23 represent that portion of the region lying west of New River; Nos. 1, 5, 6, and 23 representing that portion north of the proposed townsite. This latter area is a level country many miles in extent. The soil is generally a hard, compact clay, and in spots bears a heavy growth of greasewood; in the immediate locality of No. 23 there is a rank growth of pig-weed. Three miles from this point a 27-foot well has been dug, in which the clay extends to a depth of 12 feet, the remainder of the depth being sand. Localities Nos. 17, 18, and 19 were south of the proposed townsite, near the Mexican border, and represent an area of very level country extending parallel to New River far across the line into Mexico. The soil of this area, also, is a heavy, compact clay. The vegetation along the river and around the lakes is very rank and abundant, but on the agricultural land represented by these samples it is scarce and scattered. Over more or less of this area there are numerous hummocks, on which are found *dead* mesquit and greasewood bushes.

"Localities Nos. 3, 4, 8, 12, 13, 14, 15, 16, 26, and 27 were between the two rivers. Localities Nos. 3, 4, and 8 represent land lying north of the proposed townsite, over which a hard, compact clay soil predominates, and all of which is without vegetation. Near the point where sample 8 was obtained was a water-hole containing very saline water. A dense growth of trees, particularly willows and poplars, occurs in the river-bed at this point. Samples 14, 15, 16, and 26 were taken around the proposed townsite, and represent a large body of level land lying near the center of the agricultural district. The land has but little vegetation and is composed of hard, compact, impervious clay soil. Sample 27 represents a large area of so-called 'blown-out' land lying near Blue Lake, and a larger area of similar land lying on the west bank of the Salton River and joining the Mexican line on the south. Near sample 27 is a small body of black-alkali land.

"The locality represented by 9, 11, and 20 is that known as the 'East Side Tract,' a large area of land extending from the east bank of the Salton River to the sand hills on the east, and including all the irrigable lands to the Mexican line. These lands for some distance back from the river are much broken by large arroyos which lead into the Salton River. The soil is generally of a silty character, more or less mixed with clay in the northern part, and becoming more silty and sandy as the Mexican line is approached. Over this area the vegetation is scarce in the northern part, but near the Mexican line there is a rank growth of pig-weed, saltbush, greasewood, arrow-wood,* and sand verbena (*Abronia*). All the plants are to be found in this part of the country in abundance, and reach an enormous size.

"The country represented by localities Nos. 21 and 22 lies in Mexico, and consists of a loose, pervious, silty soil, which is overflowed annually by the waters of the Colorado River. The vegetation in these localities is very rank and abundant."

* By this name are indicated two different plants; see list, p. 42.

TABLE VII. Alkali Salts in Soils Contiguous to New River, San Diego County.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
Locality No. 1—T. 14 S., R. 14 E., Sec. 6.										
12	12	.218	.005	.001	.224	Silt; loose	8,720	200	40	8,960
24	12	.090	.013	.004	.107	Silt; very fine	3,600	520	160	4,280
36	12	.026	.019	.001	.046	ditto	1,040	760	40	1,840
48	12	.092	.014	......	.106	ditto	3,680	560	......	4,240
60	12	.136	.007	.001	.144	Silt; some sand	5,440	280	40	5,760
72	12	.155	.015	.004	.174	ditto	6,200	600	160	6,960
Total for vertical section							28,680	2,920	440	32,040
Locality No. 3—T. 12 S., R. 13 E., Sec. 36.										
10	10	.767	.010	.157	.934	Clay; slightly compact	25,567	333	5,233	31,133
22	12	.995	.009	.392	1.396	ditto	39,800	360	15,680	55,840
36	14	.172	.012	.010	.194	ditto	8,026	560	467	9,053
Total for vertical section							73,393	1,253	21,380	96,026
Locality No. 4—T. 13 S., R. 14 E., Sec. 5.										
12	12	.755	.013	.318	1.086	Silt; very fine	30,200	520	12,720	43,440
24	12	.179	.012	.019	.210	ditto	7,160	480	760	8,400
36	12	.081	.012	.005	.098	ditto	3,240	480	200	3,920
48	12	.057	.012	.009	.078	ditto	2,280	480	360	3,120
60	12	.063	.016	.009	.088	ditto	2,520	640	360	3,520
Total for vertical section							45,400	2,600	14,400	62,400
Locality No. 5—T. 12 S., R. 13 E., Sec. 33.										
12	12	.254	.020	.014	.288	Silt; very loose	10,160	800	560	11,520
16	4	.079	.010	.033	.122	ditto	1,053	133	440	1,626
30	14	.105	.007	.014	.126	ditto	4,900	327	653	5,880
42	12	.081	.012	.014	.107	ditto	3,240	480	560	4,280
54	12	.095	.014	.009	.118	ditto	3,800	560	360	4,720
72	18	.120	.006	.014	.140	Clay; compact	7,200	360	840	8,400
Total for vertical section							30,353	2,660	3,413	36,426
Locality No. 6—T. 13 S., R. 14 E., Sec. 18.										
12	12	.070	.046	trace	.116	Silty clay; compact.	2,800	1,840	trace	4,640
18	6	.244	.008	trace	.253	Silty clay; loose	4,880	160	trace	5,040
32	14	.140	.008	.140	.288	Clay; very compact.	6,534	373	6,533	13,440
44	12	.063	.009	.002	.074	Silt; very loose	2,520	360	80	2,960
60	16	.058	.019	.002	.079	ditto	3,100	993	107	4,200
72	12	.062	.010	trace	.072	ditto	2,840	40	trace	2,880
Total for vertical section							22,674	3,766	6,720	33,160

TABLE VII—Continued.

Locality No. 7—T. 13 S., R. 13 E., Sec. 11.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
6	6	.862	.019	.276	1.157	Silty clay; loose	17,240	380	5,520	23,140
12	6	.317	.008	.239	.564	Clay; compact	6,340	160	4,780	11,280
16	4	.335	.010	.009	.354	Silt; loose	4,466	134	120	4,720
18	2	.427	.009	.117	.553	ditto	2,846	60	780	3,686
30	12	.151	.001	.047	.205	ditto	6,040	280	1,880	8,200
42	12	.165	.011	.014	.190	ditto	6,600	440	560	7,600
48	6	.111	.012	.023	.146	ditto	2,220	240	460	2,920
51	3	.185	.009	.028	.222	Silty clay; compact	1,850	90	280	2,220
53	2	.121	.010	.019	.150	Silty clay; loose	807	67	126	1,000
56	3	.279	.014	.033	.326	Clay; compact	2,790	140	330	3,260
72	16	.061	.013	.014	.088	Silty clay; loose	3,253	693	747	4,693
Total for vertical section							54,452	2,684	15,583	72,719

Locality No. 8—T. 13 S., R. 14 E., Sec. 6.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
12	12	.097	.014	.017	.128	Silt	3,880	560	680	5,120
24	12	.903	.002	.173	1.078	Silt	36,120	80	6,920	43,120
Total for vertical section							40,000	640	7,600	48,240

Locality No. 14—T. 15 S., R. 13 E., Sec. 13.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
4	4	.731	.007	.075	.813	Clay; somewhat compact.	9,747	93	1,000	10,840
16	12	.642	.012	.211	.865	ditto	25,680	480	8,440	34,600
30	12	.423	.013	.154	.590	ditto	16,920	520	6,160	23,600
40	10	.301	.013	.150	.464	Clay; compact	·10,033	433	5,000	15,466
56	16	.335	.012	.323	.670	Clay; somewhat compact.	17,867	640	17,226	35,733
68	12	.388	.009	.103	.500	ditto	15,520	360	4,120	20,000
72	6	.592	.009	.080	.681	ditto	11,840	180	1,600	13,620
Total for vertical section							107,607	2,706	43,546	153,859

Locality No. 15—T. 15 S., R. 14 E., Sec. 16.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
12	12	.249	.005	1.928	2.182	Clay; lumpy	9,960	200	77,120	87,280
24	12	.621	.003	1.076	1.700	ditto	24,840	120	43,040	68,000
36	12	.476	.025	.497	.998	ditto	19,040	1,000	19,880	39,920
48	12	.396	.021	.181	.598	ditto	15,840	840	7,240	23,920
60	12	.399	.019	.170	.588	Clay; compact	15,960	760	6,800	23,520
72	12	.245	.015	.070	.330	ditto	9,800	600	2,800	13,200
Total for vertical section							93,440	3,520	156,880	255,840

Locality No. 16—T. 15 S., R. 14 E., Sec. 18. (Imperial.)

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
12	12	.478	.007	.013	.498	Clay; lumpy	19,120	280	19,920	39,420
72	12	.243	.019	.006	.268	Clay; compact	9,720	760	240	10,720
72	72	.562	.012	.018	.592		134,880	2,880	4,320	142,080
Total for vertical section							134,880	2,880	4,320	142,080

TABLE VII—Continued.

Locality No. 17—T. 16 S., R. 13 E., Sec. 33.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
9	9	.241	.009	.014	.264	Clay; lumpy.	7,230	270	420	7,920
24	15	.572	.009	.051	.632	Clay; compact	28,600	450	2,550	31,600
Total for vertical section							35,830	720	2,970	39,520

Locality No. 18—T. 17 S., R. 13 E., Sec. 20.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
12	12	.302	.013	.014	.329	Clay; lumpy	12,080	520	560	13,160
18	6	.575	.015	.426	1.016	Clay; very compact.	11,500	300	8,520	20,320
30	12	.400	.020	.136	.556	Clay; lumpy	16,000	800	5,440	22,240
34	4	.188	.017	.033	.238	Silt; very loose	2,507	240	1,320	3,167
46	12	.180	.021	.014	.215	ditto	7,200	840	560	8,600
58	12	.158	.012	.019	.189	ditto	6,320	480	760	7,570
72	14	.078	.027	.009	.114	ditto	3,640	1,260	420	5,320
Total for vertical section							59,147	4,440	17,580	80,377

Locality No. 19—T. 17 S., R. 14 E., Sec. 21.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
12	12	.480	.008	trace	.488	Silty clay; lumpy	19,200	320	trace	19,520
24	12	.333	.008	.094	.435	Clay; lumpy	13,320	320	3,760	17,400
36	12	.065	.020	.005	.090	ditto	2,600	800	200	3,600
42	6	.117	.013	trace	.130	Silty clay; compact	2,340	260	trace	2,600
54	12	.013	.025	trace	.038	Sandy; loose	520	1,000	trace	1,520
66	12	.065	.009	trace	.074	ditto	2,600	360	trace	2,960
72	6	.051	.009	trace	.060	ditto	1,020	180	trace	1,200
Total for vertical section							41,600	3,240	3,960	48,800

Locality No. 21—Mexico.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
8	8	.231	.011	trace	.242	Clay	6,159	294	trace	6,453
14	6	.736	.019	.037	.792	Clay	14,720	380	740	15,840
26	12	.316	.014	.004	.334	Clay; compact	12,640	560	160	13,360
38	12	.118	.011	.002	.131	ditto	4,720	440	80	5,240
46	8	.076	.019	.001	.096	ditto	2,280	253	27	2,560
55	9	.159	.013	trace	.172	Silty clay; lumpy	4,770	390	trace	5,160
60	5	.143	.025	.061	.229	ditto	2,383	417	1,016	3,816
72	12	.151	.020	.004	.175	ditto	6,240	80	160	7,000
Total for vertical section							54,432	2,814	2,183	59,429

Locality No. 23—T. 13 S., R. 14 E., Sec. 15.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
12	12	.508	.003	.445	.956	Silty clay; lumpy	20,320	120	17,800	38,240
24	12	.652	.003	.215	.870	Clay; compact	26,080	120	8,600	34,800
36	12	.580	.010	.080	.670	ditto	23,200	400	3,200	26,800
48	12	.424	.005	.066	.495	ditto	16,960	200	2,640	19,800
60	12	.333	.012	.183	.528	ditto	13,320	480	7,320	21,120
72	12	.617	.009	.131	.757	ditto	24,680	360	5,240	30,280
Total for vertical section							124,560	1,680	44,800	171,040

TABLE VII—Continued.

Locality No. 26—T. 15 S., R. 13 E., Sec. 25.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
4	4	.138	.007	.009	.154	Clay; compact	1,840	93	120	2,053
16	12	.362	.004	.098	.464	ditto	14,480	160	3,920	18,560
28	12	.200	.001	.065	.266	ditto	8,000	40	2,600	10,640
40	12	.163	.016	.033	.212	ditto	6,520	640	1,320	8,480
52	12	.165	.004	.023	.192	ditto	6,600	160	920	7,680
64	12	.129	.006	.019	.154	ditto	5,160	240	760	6,160
Total for vertical section							42,600	1,333	9,640	53,573

Locality No. 27—T. 15 S., R. 13 E., Sec. 34.

Depth (inches)	Thickness (inches)	Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Sulfates	Carbonates	Chlorids	Total
12	12	.044	.012	trace	.056	Silt; loose	1,760	480	trace	2,240
30	18	.032	.020	trace	.052	ditto	1,920	1,200	trace	3,120
36	6	.001	.024	trace	.025	Clay; lumpy	20	480	trace	500
42	6	.032	.017	.005	.054	Silt; loose	640	340	100	1,080
54	12	.027	.011	trace	.038	ditto	1,080	440	trace	1,520
66	12	.092	.012	.014	.118	ditto	3,680	480	560	4,720
72	6	.195	.016	.037	.248	ditto	3,900	320	740	4,960
Total for vertical section							13,000	3,740	1,400	18,140

TABLE VIII. Summary Table, showing Soluble Salts to Depth of 4 Feet. New River Region.

Locality.	Pounds per Acre. Sulfates.	Carbonates.	Chlorids.	Total.
1	17,040	2,040	240	19,320
4	42,880	1,960	14,040	58,880
5	21,253	3,020	2,393	26,666
6	17,509	2,977	6,640	27,026
7	45,752	1,694	14,100	61,546
14	71,313	2,036	29,213	102,372
15	69,680	2,160	148,280	219,120
16	89,920	1,920	2,847	94,787
18	30,340	2,780	16,527	49,627
19	37,720	1,200	3,960	42,880
21	43,579	2,024	1,007	46,610
23	96,560	840	32,240	119,640
26	35,240	1,039	8,573	44.852
27	4,880	2,720	100	7,700
Average	44,547	2,028	20,011	66,586
Minimum	4,880	840	100	7,700
Maximum	96,560	3,020	148,280	219,120

TABLE IX. Alkali Salts in Soils Contiguous to Salton River.

Locality No. 2—T. 13 S., R. 14 E., Sec. 4.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Percentages. Carbonates	Percentages. Chlorids	Percentages. Total	Physical Characteristics.	Pounds per Acre. Sulfates	Pounds per Acre. Carbonates	Pounds per Acre. Chlorids	Pounds per Acre. Total
48	48	.072	.008	.014	.094	Clay; compact	11,520	1,280	2,240	15,040

Locality No. 9—T. 13 S., R. 15 E., Sec. 2.

Depth (inches)	Thickness (inches)	Sulfates	Carbonates	Chlorids	Total	Physical Characteristics	Sulfates	Carbonates	Chlorids	Total
6	6	.343	.014	.075	.432	Clay; lumpy	6,860	280	1,500	8,640
18	12	.623	.016	.117	.756	Clay; very compact	24,920	640	4,680	30,240
30	12	.444	.017	.145	.606	ditto	17,760	680	5,800	24,040
36	6	.333	.013	.098	.444	ditto	6,660	260	1,960	8,880
48	12	.120	.013	.047	.180	Silt; some sand	4,800	520	1,880	7,200
60	12	.258	.014	.220	.492	Clay; very compact	10,320	580	8,800	19,680
72	12	.115	.013	.103	.231	ditto	4,600	520	4,120	9,240
Total for vertical section							75,920	3,480	28,740	108,120

Locality No. 10—T. 13 S., R. 16 E., Sec. 6.

Depth (inches)	Thickness (inches)	Sulfates	Carbonates	Chlorids	Total	Physical Characteristics	Sulfates	Carbonates	Chlorids	Total
11	11	.118	.006	.008	.132	Sand; fine, very loose	4,327	220	293	4,840
16	5	.101	.008	.002	.111	Sand and gravel	1,683	134	33	1,850
30	14	.106	.008	.004	.118	Coarse sand	4,046	373	187	5,506
36	6	.486	.008	.026	.520		9,720	160	520	10,400
Total for vertical section							20,676	887	1,033	22,596

Locality No. 11—T. 13 S., R. 15 E., Sec. 36.

Depth (inches)	Thickness (inches)	Sulfates	Carbonates	Chlorids	Total	Physical Characteristics	Sulfates	Carbonates	Chlorids	Total
14	14	.527	.017	.150	.694	Clay; shaly	24,598	798	7,000	32,386
23	9	.282	.012	.028	.322	Silt; very loose	8,460	360	840	9,660
35	12	.189	.014	.079	.282	ditto	7,560	560	3,160	11,280
41	6	.238	.011	.009	.258	Clay; compact	4,760	220	180	5,160
53	12	.192	.011	.009	.212	ditto	4,680	440	360	8,480
57	4	.087	.014	.009	.110	Silt; loose	1,160	186	120	1,466
Total for vertical section							54,213	2,559	11,660	58,432

Locality No. 20—T. 16 S., R. 16 E., Sec. 22.

Depth (inches)	Thickness (inches)	Sulfates	Carbonates	Chlorids	Total	Physical Characteristics	Sulfates	Carbonates	Chlorids	Total
12	12	.161	.010	.033	.204	Clay; shaly	6,440	400	1,320	8,160
30	18	.151	.012	.005	.168	ditto	9,060	720	300	10,080
42	12	*	-----	-----	*	-----	-----	-----	-----	-----
54	12	.022	.010	trace	.032	Sandy	880	400	trace	1,280
72	18	.017	.008	.005	.030	ditto	1,020	480	300	1,800

*Sample spoiled by becoming wet.

Locality No. 22—8 miles south from Sec. 8, R. 17 E., Mexican line.

Depth (inches)	Thickness (inches)	Sulfates	Carbonates	Chlorids	Total	Physical Characteristics	Sulfates	Carbonates	Chlorids	Total
12	12	.224	.012	.001	.237	Silt; very fine	8,960	480	40	9,480
24	12	.341	.012	.033	.386	ditto	13,640	480	1,320	15,440
36	12	.376	.012	.014	.302	ditto	15,040	480	560	12,080
48	12	.275	.014	.047	.336	ditto	11,000	560	1,880	13,440
Total for vertical section							48,640	1,900	3,800	50,440

TABLE X. Summary Table, showing Soluble Salts to the Depth of 4 feet in localities near Salton River.

Locality.	Pounds per Acre.			
	Sulfates.	Carbonates.	Chlorids.	Total.
2	11,520	1,280	2,240	15,040
9	61,000	2,380	15,820	79,200
11	48,103	2,190	11,390	61,596
22	48,640	1,900	3,800	50,440
Average	42,314	1,938	8,312	52,564
Minimum	11,520	1,280	2,240	15,040
Maximum	61,000	2,380	15,820	79,200

Even a cursory glance at the preceding tables shows that the distribution of the silty and clay lands is very much "spotted"; for while there is a general predominance of clay on the west, contiguous to New River, especially in the westward bend of that channel, in range 13, there are also two silt localities (Nos. 5 and 7) in the same range, together with localities 1, 4, 6, 8, and 19 in range 14. Elsewhere we find in ranges 14 and 15, localities 2 and 9 with compact clay soils, although generally silts are predominant on the Salton. Only detailed mapping can therefore segregate the several areas; but each one can test the soil character easily by boring or digging, or preferably by the irrigation test, *i. e.*, noting how rapidly the water will penetrate to the depth of from three to six feet, according to the crops it is intended to plant. In the absence of ditches, water sufficient for the purpose can be hauled to the spot.

That the two deep vertical sections do not represent the worst of the land is shown in the more shallow sections from near New River, where eight out of fourteen of the more shallow sections exceed the deep section from New River bank in the total alkali present. In the case of the shallow sections from near Salton River, however, the condition does not appear to be as bad, for but one out of four exceeds the river-bank section in the total alkali present in the first four feet.

In looking closely at the lesser sections, as well as at those taken from the river banks, there will be seen a general tendency for a break to occur in the total alkali content after the second foot, which generally seems to carry a larger amount of salts than the top foot. This break will serve largely as a saving clause for the lands, in many cases rendering it possible to reduce the alkali in the upper layers of the soil below the maximum of tolerance for crops. Particularly will this be true in growing alfalfa, which has been found to resist a surprising amount of alkali *when it is once well rooted.* In this same region excellent fields have been grown where the soil carried as high as 110,000 pounds of alkali to the depth of six feet, and 79,760 pounds to the depth of four feet. The figures showing the alkali content of two of the alfalfa fields near Yuma are herewith presented.

Sample 28 was taken two miles south of Yuma in Mr. C. C. Dyer's alfalfa field.

Sample 31 was taken from the alfalfa field adjoining Mr. Smith's dairy, one and one half miles south of Yuma. The soil was moist to a depth of 5 feet.

TABLE XI. Showing Soluble Salts in Yuma Alfalfa Lands.

	Physical Characteristics.	Depth (inches)	Thickness (ins.)	Percentages.				Pounds per Acre.			
				Sulfates	Carbonates	Chlorids	Total Salts	Sulfates	Carbonates	Chlorids	Total Salts
Sample 28.	Silt; very loose	12	12	.402	.010	.012	.424	16,080	400	480	16,960
	ditto	24	12	.683	.013	.038	.734	27,320	520	1,520	29,360
	ditto	36	12	.456	.008	.016	.480	18,240	320	640	19,200
	ditto	48	12	.328	.008	.014	.350	13,120	320	560	14,000
				.467	.009	.020	.499	74,760	1,560	3,200	79,520
Sample 31.	Silt; loose	12	12	.356	.008	.018	.382	14,240	320	720	15,280
	ditto	24	12	.829	.010	.031	.870	33,160	400	1,240	34,800
	ditto	36	12	.416	.008	.044	.468	16,640	320	1,760	18,720
	ditto	48	12	.248	.009	.017	.274	9,920	360	680	10,960
	Clay; lumpy	60	12	.342	.009	.027	.378	13,680	360	1,080	15,120
	Silty clay; lumpy	72	12	.371	.008	.007	.386	14,840	320	280	15,440
				.427	.009	.024	.459	102,480	2,080	5,760	110,320

It is safe to say that much of the land near Salton River will produce excellent crops of this forage plant if it can once be started. The young plants of this crop are quite sensitive to alkali, and in most instances it would be necessary to reduce the salts in the upper layer of the soil by heavy and deep irrigation in order to secure a stand. It took four years to secure good stands in the above fields.

That it is possible to do this in most cases on the Salton River silts can be seen by referring not only to the sections from the river bank, but also to the lesser sections. In a previous publication from this Station (Bulletin No. 133), Dr. Loughridge has shown that when young this plant will stand in the neighborhood of 12,000 pounds of salts. When the distribution of the alkali in the silt soil is considered in connection with the rapidity of percolation, as shown by the experiments previously discussed, the condition for crop-growing on these soils seems quite favorable. There is, however, a distinct disadvantage in the case of the silt soil for crops which require open culture, namely the high capillary power; which will tend to bring up the alkali rapidly when exposed to surface evaporation after irrigation. To successfully cultivate these lands and not experience a very serious "rise of alkali," it is very imperative that they be at all times kept in good tilth by frequent and deep cultivation. *If this be not done there is almost sure to follow a very serious alkali condition in the upper layers of the soil.*

Looking again at the tables and profiles, we find throughout that the carbonates are insignificant, and, except so far as there is a likelihood that under heavy irrigation they may be formed in the future, can be left out of consideration at present. As to the chlorids, the land near New River seems to carry the larger amount; which might be expected from what has been said heretofore. It shows the enormous range of 100 to 148,280 pounds per acre to a depth of four feet; and when the generally high chlorid content of these clays is considered, together with their other unfavorable properties, it is apparent what a hopeless task it will be to attempt to handle them successfully. The people who have been unfortunate enough to settle upon these dense, hard clay soils should change to some more auspicious location, the sooner the better.

THE IRRIGATION WATER.

A consideration of the soluble salt content of the available irrigation water is of nearly as great importance as a like consideration of the soils themselves; for when water highly impregnated with alkali is used for irrigation purposes, all the alkali in that portion of the water which evaporates from the surface will be left in the land, and if the water be very bad the land may soon become so highly charged with alkali from this cause alone that it will not grow profitable crops. This fact is the more important in case the lands to be irrigated are themselves as heavily loaded with alkali as those under consideration; for the salts left after the evaporation of the water become an added evil with which to contend, and may prove "the straw that breaks the camel's back."

It is not easy to state absolute figures as to what constitutes an excess of salts in water to be used for irrigation purposes, for not only must the nature of the saline content of the water be considered, but also that of the land to be irrigated. The far more variable factor, the quantity and frequency of irrigation required, also demands attention.

Speaking along this line in a previous publication, the Director of the Station has said: "Broadly speaking, the extreme limit of mineral content usually assigned for potable waters, viz: 40 grains per gallon, also applies to irrigation waters. Yet it sometimes happens that all or most of the solid content is gypsum and epsom salt; when only a large excess of the latter would constitute a bar to irrigation use. When, on the contrary, a large portion of the solids consists of carbonate of soda, or common salt, even a smaller proportion of salts than 40 grains might preclude its regular use, depending upon the nature of the soil to be irrigated. For in a clay loam, or heavy adobe, not only do the salts accumulate nearer the surface, but the sub-drainage being slow and imperfect (unless the land is underdrained), it becomes difficult, or impossible, to wash out the saline accumulations from time to time, as is readily feasible in sandy soils."

Subjoined is a table showing analyses of the water of the Colorado River which is used for irrigation purposes in the region. In the same table are shown analyses of water from two of the lakes, and of a well in the region, all the analyses having been made by Mr. Snow.

TABLE XII. Water Analyses.

	Colorado River "near Head Gates."				Blue Lake.		Well at Cameron Lake.		Cameron Lake.	
	Turbid.		Clear.							
	Grains per Gallon....	Parts in 10,000....	Grains per Gallon....	Parts in 10,000....	Grains per Gallon.	Parts in 10,000....	Grains per Gallon.	Parts in 10,000....	Grains per Gallon.	Parts in 10,000....
Total residue by evaporation	79.73	13.65	51.11	8.75	26.57	4.55	43.69	7.38	104.96	17.97
Soluble in water after evaporation	33.57	5.75	33.59	5.75	16.94	2.90	23.95	4.10	78.56	13.45
Insoluble in water after evaporation	38.55	6.60	9.93	1.70	6.42	1.10	15.07	2.58	16.65	2.85
Organic matter and chemically combined water	7.59	1.30	7.59	1.30	3.21	.55	4.67	.80	9.75	1.67
The soluble part consists of—										
Sodium and Potassium sulfates (glauber salt, etc.)	19.35	3.32	21.20	3.64	2.33	.40	21.22	3.64	40.45	6.93
Sodium chlorid (common salt)	6.75	1.16	6.82	1.16	4.09	.70	2.73	.46	23.87	4.08
Sodium carbonate (sal soda)	7.42	1.27	5.57	.95	......	......	trace	trace	14.24	2.44
The insoluble part consists of—										
Calcium and magnesium carbonates	21.32	3.65	9.35	1.60	5.55	.95	18.73	2.35	sm.	
Calcium sulfate (gypsum)					trace	....	sm.	.....	16.36	2.80
Silica	17.23	2.95	.58	.10	.87	.15	1.34	.23	.29	.05
Residue upon slight ignition	Browns.		Does not blacken.		Blackens.		Browns.		Blackens.	

In connection with the above table we give two analyses of the Colorado River water from the Eleventh Annual Report of the Arizona Experiment Station. Each analysis represents water from samples taken over periods of a week:

	Grains per U. S. Gallon.	
	Jan. 22–28. Low water.	Apr. 25–May 1. Medium flow.
Silt by volume	.17%	.392%
Silt by weight	.058%	.115%
Total soluble solids	58.41	33.24
Sodium chlorid	21.07	10.26
Permanent hardness; stated as calcium sulfate	9.67	8.24

These analyses show the composition of the water to be quite variable at different periods of the same season and in different seasons. It will be noted that the maximum concentration shown is over 58 grains of soluble salts per gallon when the water is at a low stage, and that these fall to about 30 grains per gallon during the period of medium flow. In the Arizona report previously referred to it is further stated that "the total soluble solids were observed to average as low as 25 parts per 100,000 (14.5 grains per gallon) for months at a time." It is during this time, so far as possible, that the water would be mainly used for irrigation purposes, thus indicating the water to be of fair quality for use upon the silt soils. The quantity of soluble salts is influenced by the stage of the water and by the seepage from irrigation districts; the latter materially influences the character of the salts present. That this is so may be seen by comparing the proportion of sodium chlorid present at the several times, for at one period (in 1900) this ingredient reaches a maximum of one third of the total soluble salts, and in another constitutes only about one fifth. The carbonates appear to form about one sixth of the total. While this water could be used with impunity upon the silts, it would but increase the extremely undesirable saline conditions of the clay soils of the region.

Manner of Irrigating Alkali Lands.—The manner of using water upon these lands, in order that the salts may not be brought to the surface and thus increase the saline condition, especially of the upper foot, is of great importance in handling these strongly saline lands. The general principle has been indicated at several points in this publication, viz: that of leaching down the salts in the soil itself, thus reducing the amount of alkali in the upper foot, and taking it out of reach of the tender rootlets of the young plants especially. The water under these conditions should not be kept on the tract for a less period than twenty-four hours, and for a thorough leaching-down a considerably longer time should be given. The behavior of the soil when irrigated should be the first thing tried in order to test the possibilities of successful cultivation; taking into consideration the known fact that the rapidity of absorption ("taking water") gradually increases under cultural conditions, largely because of the loosening of the soil by the crop roots, as well as by tillage.

"It is not practicable, as many suppose, to wash the salts off the surface by a rush of water, even when visibly accumulated there, as they instantly soak into the ground at the first touch. Nor is there any sensible relief from allowing the water to stand on the land and then drawing it off; in this case also the salts soak down ahead of the water, and the water standing on the surface remains almost unchanged. In very pervious soils, and in the case of white alkali, the washing-out can often be accomplished without special provision for underdrainage, by leaving the water on the land sufficiently long. But the laying of regular underdrains greatly accelerates the work, and renders success certain."*

After the salts have been washed down so as to relieve the surface soil of any excess injurious to the germination of seeds or the life of young seedlings, irrigation by flooding must, except in the case of crops that fully shade the ground, be practiced only at long intervals, if at all. To prevent the "rise of the alkali" that is sure to follow continued surface flooding, the water should thereafter be applied in deep furrows, from which the water will chiefly soak downward and sideways only, and preferably not rise to the surface at all. *Evaporation from the soil surface is the cause of the accumulation of the salts at and near that surface;* to prevent it it is necessary to avoid wetting the latter, and this is best brought about by deep-furrow irrigation, which, at the same time, allows of a considerable saving of water, while tending to deepen the root-system and so to bring it out of reach of the destructive heat and drought of summer.

Diagram V illustrates the manner in which irrigation water can be used so as to prevent its reaching the surface to any such extent as to cause a serious amount of evaporation. The solid lines represent the manner of penetration of water from furrows 8 inches deep, as actually observed at the Southern California substation near Pomona (see Bulletin No. 138, page 38) in two different soils, of which the heavier (to the left) resembles most nearly in texture the silt and loam soils of the Salton Basin. The dotted lines show the effects that would have been produced had the furrow been made deeper to the extent of 7 inches; in which case the water would have reached the surface only at the edges of the furrows, so that when these are subsequently closed by plowing there would be practically no surface evaporation, and no after-cultivation would be required to prevent crusting-over.

* Bulletin No. 128, California Experiment Station.

It is evident that with the proper implements for the purpose, such deep-furrow irrigation, to prevent the re-ascent of alkali near the surface, could be made a ready means of utilizing a large proportion of the alkali lands here in question without any difficulty, and with a

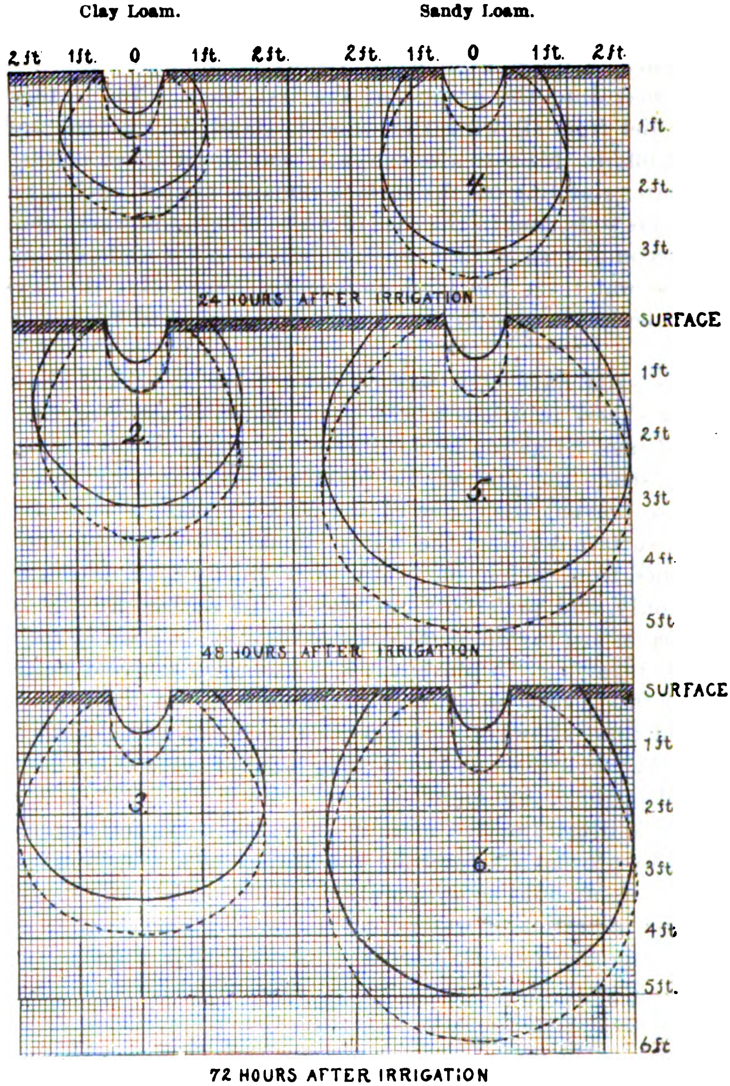


DIAGRAM V. Percolation experiments. Spread of water from deep furrows in heavy and light soils.

material saving of water and cost of surface cultivation, in addition to the advantages secured in the deeper penetration of the roots into materials which, as the sections of the river banks show, are but very slightly tainted with alkali salts.

Of course, this method is best applicable to crops grown in rows, as orchards and vineyards, sorghum, corn, etc. For broadcast crops it can only be used in rather pervious soils, which can be irrigated by lateral seepage when laid off in "lands" of a width proportionate to the rapidity of water-penetration. In the Mussel Slough district such lands are made about 50 feet wide; but as the soils here in question are not nearly as open, they would have to be made narrower. By following this method carefully and intelligently, most of the lands of the silty character can probably be successfully cultivated to crops not too sensitive to alkali, provided they are not underlaid at too shallow a depth by the impervious clay; as is frequently the case between the two rivers. The clay will of course arrest the alkali-laden irrigation water in its downward course, and thus from a depth of a few feet it will be constantly reascending toward the surface. Such land will be hard to cultivate successfully without actual underdrainage, except to the hardiest crops, such as sorghum, barley, and shallow-rooted plants generally. Alfalfa can hardly be a success on land having the clay within less than five feet; for fifteen or twenty feet are ordinary depths of penetration for its roots. When the clay layer is not of great thickness and is underlaid by silty materials, success in tree-planting may be attained by blasting with giant powder; as is commonly done with hardpan of other kinds, when a good soil material is known to lie beneath. *In the case of alfalfa, modiola, and other plants which eventually cover and shade the ground very fully, the evaporation through the roots and leaves will largely prevent the rise of the alkali, even when flooding is practiced.*

It is clear that, in this region at least, no farmer can afford to be ignorant of the undersoil conditions upon his land; and if heavy irrigation is practiced, he should make absolutely sure by personal observation that the soil is actually being wetted to the depth of five or six feet, and note how long it takes to bring about this wetting. Such examination can be made either by means of a long-shafted posthole auger or two-inch carpenter's auger; or more quickly, after some practice has been acquired, by the use of a pointed prod made of quarter-inch square steel, with a loop for a cross-handle, which can be pushed down by twisting it slightly alternately in opposite directions. This rod also serves admirably for preliminary tests of the subsoil in the examination of lands.

Drainage.—The natural slope of these lands toward Mesquit Lake, as shown by the contour lines of the map, together with the good percolative power of the lighter silty and sandy lands, renders the leaching of their salts into drainage ditches running toward the lake perfectly feasible, and simplifies the problem of ultimate successful cultivation.*

* In studying the contour lines on the map it should be noted that the small figures appearing on these lines do not indicate directly the elevation above the sea, but only the relative altitude of the several points. The point of reference used is 1,000 feet above sea level, and the true altitude (or rather depression) can be found by deducting 1,000 from these figures.

For the permanent betterment of the lands, those interested should, by community action, devise a thorough system of drainage. Such a system might at the beginning be a number of deep ditches, into which the alkali-charged seepage-water could enter from flooded areas, until the far preferable plan of tiling could be profitably introduced.

An illustration in point obtains in the case of the Patterson ranch, at Oxnard, a portion of which became much "salt-stricken," but where, after the construction of a deep drainage canal into which were led laterals, there was, and is, a constant removal of the accumulated salts at a surprisingly rapid rate.

VEGETATIVE CHARACTERISTICS OF THE SALTON BASIN.

That the vegetation of any region supplies important information concerning its agricultural adaptations is so well known in practice as not to require discussion. It is especially instructive in its application to alkali lands; and Mr. Snow was therefore instructed to observe and collect for determination specimens of all the plants to be found on the territory explored by him.

"While the adaptation or non-adaptation of particular alkali lands to certain cultures may be determined by sampling the soil and subjecting the leachings to chemical analysis, it is obviously desirable that some other means, if possible available to the farmer himself, should be found to determine the reclaimability and adaptation of such lands for general or special cultures. The natural plant growth seems to afford such means, both as regards the quality and quantity of the saline ingredients. The most superficial observation shows that certain plants indicate extremely strong alkali lands where they occupy the ground alone; others indicate preëminently the presence of common salt; the presence or absence of still others forms definite or probable indications of reclaimability or non-reclaimability. Many such characteristic plants are well known to and readily recognized by the farmers of the alkali districts. 'Alkali weeds' are commonly talked about almost everywhere; but the meaning of this term—*i. e.*, the kind of plant designated thereby—varies materially from place to place, according to climate as well as to the quality of the soil. Yet if these characteristic plants could be definitely observed, described, and named, while also ascertaining the amount and kind of alkali they indicate as existing in the land, lists could be formed for the several districts, which would indicate, in a manner intelligible to the farmer himself, the kind and degree of impregnation with which he would have to deal in the reclamation work, thus enabling him to go to work on the basis of his own judgment, without previous reference to this Station." *

The season at which the exploration took place (Christmas vacation)

* Bulletin No. 128, California Experiment Station, p. 35.

was of course unfavorable to the finding of all the kinds of plants that might occur somewhat later. Only twenty-two species in all were collected, and these were submitted for determination to Mr. Joseph Burtt Davy, Assistant Botanist to the Station. Mr. Davy's results and comments are given herewith, together with the annotations of Mr. Snow, placed in brackets.

ANNOTATED LIST OF PLANTS FROM THE SALTON BASIN.

(Collected by F. J. Snow.)

By Jos. Burtt Davy, Assistant Botanist.

CRUCIFERÆ.

1. *Lepidium lasiocarpum*, Nutt. *Pepper-cress.*

Five miles south of proposed townsite. [Very abundant near Mexican line.]
Salton River, near Patton's camp. [Abundant in scattering places.]
T. 13, R. 15. [Scarce, except in small patches.]
Mexico: 15 miles from line. [Scarce.]

A common desert annual, probably tolerant of some alkali, as are many other species of the genus, but not necessarily indicative. It is sometimes found also in moist alluvial soils, and ranges from Santa Barbara through the Mojave plateau region and, east of the Sierra, northward to Keeler.

ZYGOPHYLLACEÆ.

2. *Larrea tridentata* (DC.) Coville. *Creosote-bush.*

Along Salton River. [Abundant in places along the river. Very abundant toward Mexican line.]

Locality 9, T. 13, R. 15. [A few scattering live bushes.]

Mexico: 15 miles from line. [A few bushes. Becomes very abundant near Mexican line along Salton River.]

One of the most characteristic desert plants, occurring almost throughout the Lower Sonoran zone from the bottom of Death Valley about 300 feet below sea level to an altitude of 5,500 feet in the Panamint Mountains. It is not an alkali plant, and usually grows on well-drained soils well above the alkali line; but at its lower limit a few scattered specimens are often found in the *Atriplex polycarpa* belt, in a mixture of gravel and clay with some visible trace of alkali.

LEGUMINOSÆ.

3. *Astragalus mortoni*, Nutt. *Morton's loco-weed; "Loco-weed"; "Wild pea."*

Salton River bed; "if cattle eat, will go crazy." [Scattering plants along the river-bed.]

New River bed. [A number of plants near north end of river-bed.]

Moist grounds along the eastern base of the Sierra Nevada, in the vicinity of Mono Lake, and northward to the interior of Oregon and Utah. Well known as "a deadly sheep poison." We have no information as to its tolerance of alkali, but other species of the genus are characteristic alkali plants.

4. *Prosopis juliflora* (Swartz) DC. *Mesquit-tree; Algaroba; Honey mesquit.*

Near Mexican line—a few miles from Blue Lakes. [Abundant.]

Characteristic of desert areas with moist subsoil. It sometimes occurs on the edge of alkali marshes in company with *Atriplex canescens* and *Suæda suffrutescens*, where a slight alkali efflorescence or thin crust occurs, but above the heavily alkaline soils, though below the *Atriplex polycarpa* belt. I have found it in somewhat alkaline soils near Bakersfield. Though tolerant of some alkali, it is not an alkali indicator. Its altitudinal range varies from 328 feet below sea level, to 5,650 feet above.

FICOIDEÆ.

5. *Sesuvium portulacastrum*, L. *Lowland purslane.*
New River channel. [Found at the north end of New River channel; but few plants to be seen elsewhere.]

A very characteristic plant of moist alkali and saltmarsh soils both in the interior and along the seacoast. It is found in alkali marshes in the Mojave Desert and the Tulare Valley, and in the Great Basin region from northern Nevada to Colorado and New Mexico. It is said that in the interior it often occurs with much broader leaves than is usual when growing along the seashore. We have no analysis showing the tolerance of alkali by this plant, but it has been found growing in soils so heavily impregnated with salts that scarcely any other plants grew there.

COMPOSITÆ.

6. *Bigelovia veneta* (H. B. K.) Gray. *Bigelovia.*
Ten miles south of Blue Lakes. [Abundant.]
Alkali meadow at monument east of Salton River. [Abundant.]

A plant of the Lower Sonoran zone, common in moist alkali soils, but apparently not tolerant of a very large percentage. In the Bakersfield region the salt tolerance of this plant was found to vary from 1,800 pounds of salts per acre to 24,320 pounds. It was not found in soils heavily charged with alkali.

7. *Baccharis* sp. (imperfect material). *Sausal; Baccharis;* (also *Arrow-wood*, in part).
Salton River bed. [Found only in river-bed in numerous places.]

Our species of *Baccharis* are swamp plants, usually growing on the borders of rivers and streams or in "washes." As a rule they are found in fresh water, but at least one species (not this one) sometimes occurs in slightly alkaline water. Two other species, *B. emoryi*, Gray, and *B. sergiloides*, Gray (to neither of which does the specimen appear to belong), occur in the Colorado Desert region.

8. *Pluchea sericea* (Nutt.) Coville. *Cachimilla; Arrow-wood.*
Salton River bed.
New River.
New River channel.
} [Abundant along portions of the river channels and banks.]
T. 13, R. 15. [Scarce.]

Reported as occurring along sandy borders of streams from Ventura County eastward to Utah and south through Arizona to New Mexico. Both of our species of *Pluchea* frequent moist alkali swamps, and one of them occurs both in the interior in the Suisun marshes and in the saltmarshes of San Francisco Bay. The amount of alkali tolerated is evidently considerable, as *P. sericea* occurs in association with Alkali tussock-grass (*Sporobolus airoides* (Torr.) Thurb.) and Salt-grass (*Distichlis spicata* (L.) Greene) in the Mojave Desert plateau region.

HYDROPHYLLACEÆ.

9. *Nama hispidum*, Benth.
Salton River bed. [Scarce, except in certain portions of the river-bed.]

A desert annual, apparently restricted to the Colorado Desert, and probably not indicative of alkali.

BORAGINACEÆ.

10. *Coldenia palmeri*, Gray.
Sample 10, T. 13, R. 16. [On sandy, high lands. Not very abundant.]

A dwarf, desert perennial occurring on sand-hills along the Colorado and lower part of the Mojave and adjacent Arizona. (*Bot. Calif.*)

11. *Heliotropium curassavicum*, L. *Wild heliotrope.*
Along Salton.
New River.
New River channel.
} [Abundant along the river-bed.]
Alkali meadow at monument east of Salton River. [Abundant.]

A nearly cosmopolitan weed, common in sands of the seashore, and in moist alkaline soils of the interior. It generally indicates the presence of alkali and moisture, but is sometimes found in soils apparently free from alkali.

AMARANTACEÆ.

12. *Amarantus chlorostachys*, Willd. *Pigweed.*

Salton River near Patton's camp. [Scattering dead plants, with here and there live plants of rank growth. To the west, about 2 miles, they thrive and attain a very rank growth. It is also found east of Salton River near the Mexican line.]

A semi-tropical weed, probably naturalized.

13. *Amarantus palmeri*, Wats. (?)

Sample 11, T. 13, R. 15. [Scattering plants; abundant toward the Mexican line.]

A desert species, apparently indigenous to the Colorado Desert and Rio Grande regions. The Amaranths are such omnivorous, weedy plants that they can not be relied upon as alkali indicators.

CHENOPODIACEÆ.

14. *Atriplex lentiformis* (Torr.) Wats. *Lens-fruited saltbush.*

New River. [Found scattered in New River country; abundant in places and in river-bed.]

Mexico: 15 miles from line. [Scarce in this locality; but abundant near Mexican line.]

Alkali meadow at monument east of Salton River. [Abundant.]

A desert species, ranging from the Tulare Valley to the Colorado Desert and eastward through Arizona. We have no record as to its tolerance of alkali, but the list of localities in which it has been found and the plants with which it is associated, indicate that it is an alkali plant.

15. *Atriplex polycarpa* (Torr.) Wats. *Scrub saltbush;* called "*Greasewood*" in the Mojave Desert, but not the "*Greasewood*" of the Great Basin region.

Mexico: 15 miles from line. [Abundant in certain localities near Mexican line.]

A characteristic desert species, ranging through the Lower Sonoran zone from the Tulare Valley through the Mojave and Colorado deserts to the Williams River in Arizona. Common in clayey valley bottoms, usually in dry soils. Analyses of scrub saltbush soils near Bakersfield show that its tolerance of salts ranges from 840 pounds to 78,000 pounds per acre.

16. *Atriplex canescens* (Pursh) James. *Shad scale;* sometimes called "*greasewood.*"

Sample 9, T. 13, R. 15. [Many dead bushes on small hummocks. A few live bushes, which are very large, are found scattered near.]

Sample 11, T. 13, R. 15. [Many dead bushes are found in this vicinity.]

T. 13, R. 15. [Many dead bushes on small hummocks; also scattering live bushes.]

Near Mexican line, a few miles from Blue Lakes. [Abundant near the lake.]

Mexico: 15 miles from line. [Scarce; but very abundant near the line on Salton River.]

A common and characteristic species, occurring in dry soils both in the Upper and Lower Sonoran zones in the Mojave and Colorado deserts, and in the Great Basin region from northern Nevada and Colorado to New Mexico. It does not appear to reach the Tulare Valley. It occurs in dry soils, on mountain slopes at altitudes ranging between 2,300 and 4,700 feet, and does not seem to be indicative of the presence of alkali. Like the Mesquit and Creosote-bush, it is sometimes found sparingly in slightly alkaline soils at its lower limit.

17. *Atriplex* sp. (immature).

Sample 8, T. 11, R. 14. [A few scattering dead bushes.]

Sample 9, T. 13, R. 15. [Dead bushes are found on small hummocks.]

18. *Suæda* sp. (immature). *Saltwort; Glasswort.*

Salton River bed. [Abundant along the river-bed.]

New River. [Abundant along the river-bed.]

The saltworts are characteristic alkali indicators, and are not known to occur elsewhere than in moist alkali soils. The total amount of salts tolerated has a wide range of variation, running from 3,700 pounds to 153,000 pounds per acre; but saltwort has been found in greatest luxuriance where the total amount of salts was 130,000 pounds per acre. The saltworts appreciate more common salt (sodium chlorid) than many other characteristic alkali plants, but appear to be somewhat easily affected by salsoda (sodium carbonate).

POLYGONACEÆ.

19. *Rumex* sp. (immature). *Dock.*
Along Salton. [Abundant in places along the river bank.]
Salton River bed. [Abundant in places along the river-bed.]
At monument east of Salton River. [Abundant.]
Two or three species are found in moist places in the Mojave and Colorado deserts.

GRAMINEÆ (TRUE GRASSES).

20. *Leptochloa imbricata*, Thurb. *Alkali slender-grass.*
Near Salton River bed, 15 miles from line. [Not abundant.]
Common in moist places and alkali plains from the Tulare Valley through the Colorado Desert to Lower California, and eastward into Mexico and Texas. A somewhat stout perennial, 1 to 3 feet high, "abundant in fields and gardens, thrifty on alkali plains and near soft [salt?] water; abundant in August and September, when alfalfa is dried up; a good forage plant, cut and fed to animals." (*Dr. Ed. Palmer.*)

GNETACEÆ.

21. *Ephedra* sp. (immature).
Ten miles from Blue Lakes. [Abundant near the lake and along New River near the Mexican line.]
Characteristic desert shrubs, said to be sometimes found in alkali soils.

UNCLASSIFIED.

22. Dwarf annual (immature and not recognized).
Sample 8, T. 11, R. 14. [Only a few plants to be found.]
Sample 9, T. 13, R. 15. [Only a few plants to be found.]

The list of plants here given is notable for the absence of most of the species considered elsewhere as prominent alkali indicators. We miss at once the salt- or alkali-grass (*Distichlis*), the "greasewood" of Nevada (*Sarcobatus*) and that of the San Joaquin Valley (*Allenrolfea*), the samphire (*Salicornia*), and the tussock-grass (*Sporobolus airoides*). Of the saltbushes proper (*Atriplex*), two (*A. polycarpa* and *lentiformis*) appear elsewhere as species indicating the probable presence of considerable alkali, while the other two species observed are not known as alkali plants. The two plants that may be considered as indicators of strong alkali, especially of common salt, are the saltwort (*Suæda*) and the lowland purslane (*Sesuvium*); their indication is strengthened by their occurence in the river channels, at whose level the profiles (pp. 20 and 21) show an abundance of salt. But as a whole, the collection made does not speak of "irreclaimable" alkali land, so far as we know their habits. The heliotrope will grow luxuriantly in non-saline lands, but also where common salt can be seen by the seaside. The creosote bush (*Larrea*), the pepper-cress (*Lepidium*), the pigweeds (*Amarantus*), the Bigelovia (yellow-flowered, sometimes called green sage) are not plants addicted to alkali lands. Taken as a whole, the native vegetation does not altogether confirm the unfavorable impression derived from the leaching of the soil samples. It is hoped that a more detailed examination of the flora at a more favorable season, soon to be undertaken, will throw more light on these questions.

CLIMATE OF THE SALTON BASIN.

The high summer temperature and dryness of the air in the Salton region are well known, being in this respect similar to the rest of the Colorado Desert. While the thermometer during summer usually rises to and above 100° Fahr. (124° having been recorded twice at Salton during 1901), the heat is not oppressive, on account of the dryness of the air, which evaporates the perspiration as soon as formed. The nights are usually decidedly cool to the sensation. The winter temperatures are in strong contrast to the summer heat, as will be seen from the small table, given below, of observations made by Mr. Snow during December, 1900, and January, 1901. It will be noted that a minimum temperature of 13° occurred on January 2d, so that ice two inches thick formed near camp. Such a temperature would at once prohibit the culture of citrus fruits, but may occur only locally, on low ground. Still, the run of December temperatures, from observations all over the region, indicates clearly that "semi-tropic" growths will incur considerable risks, unless protected in winter.

Morning Temperatures Observed in Salton Basin at 8 o'clock.

1900.		1900.		1901.	
Dec. 22	23°	Dec. 27	21°	Jan. 1	38°
23	*21	28	25	2	13
23	†70	28	††73	3§	23
24	‡24	29	28	4	30
25	23	30	26	5	40
26	20	31	24	6	30

* Dec. 23. Ice in washpan and on pond two inches thick.
† Dec. 23. For the day.
‡ Dec. 24, 25, 26, and 27. Ice in ponds.
†† Dec. 28. For the day.
§ Jan. 3. Surveyors' Camp 17.

CROPS FOR THE SALTON BASIN.

As to crops for the silt soils of this region, it must be said that the showing here made is not at all encouraging for extensive fruit-growing at the present time. While there may be localities in the region which could grow the fruits more tolerant of alkali and dry heat, yet we deem it unwise at present to encourage the planting of fruit, except the date-palm, to any considerable extent. The date-palm would doubtless be one of the fruits which could be most successfully grown, taking into consideration both the climate and the alkali soils. To this might be added olives, figs, table, sherry, and port grapes; and on the sandier lands, almonds, peaches, and some of the Japanese plums (all on Myrobalan stock) might be grown. Of ordinary crops, alfalfa, barley, sorghum, and beets for stock food, together with the saltbushes, are those that will be most likely to succeed before drainage to carry off the alkali salts has been made effective. Among the vegetables, the egg-plant, melons, cucumber, carrot, celery, asparagus, onion, sea-kale, and New Zealand spinach are those most likely to succeed.

It must not be forgotten that high summer temperature will militate materially against the production of the ordinary deciduous fruits, even after the lands have been successfully leached of their alkali to the extent necessary to permit the growth of such trees. The effects of hot northers upon these trees in other parts of the State indicate plainly what is likely to be the effect of the normal atmospheric conditions of the Colorado Desert upon them. The cultural experience had at Indio will be valuable in determining the reasonable prospects for successful culture of several crops, always keeping in mind that the light sandy soils of that portion of the region, containing but little alkali and easily leached of what there is by flooding, are more easily handled than those of the alluvial area here in question.

The following list of possible crops for alkali soils has been compiled by Mr. Joseph Burtt Davy, Assistant Botanist of the Station. It should be understood that while the plants mentioned in this list are all more or less alkali-resistant, yet the extreme climatic conditions existing in the Salton Basin render the actual success of many very questionable, although worthy of trial. The "toleration" list will aid in making selections for experiment.

POSSIBLE CROPS FOR ALKALI SOILS.

EDIBLE FRUITS.

Strawberry tomato (*Physalis pubescens*, L.).

Cape gooseberry (*Physalis peruviana*, L.).

Date-palm (*Phœnix dactylifera*, L.). In Arabia it is said to grow in soil "strongly impregnated with salt," and that "the water for irrigation may be slightly brackish."

Oleaster (*Elæagnus augustifolia orientalis*, Schlecht). Produces the fruit known as "Trebizonde dates."

Olive (*Olea europæa*, L.). The Mission variety should be first tried.

Black mulberry (*Morus nigra*, L.). The Black Persian is probably derived from this species. It is likely that other species, also, would tolerate alkali.

Grape (*Vitis vinifera*, L.), especially the southern (sherry and port) varieties.

Golden currant (*Ribes aureum*, Pursh.) is said to tolerate an alkaline soil. It is also known as the Missouri, Utah, Utah hybrid, and Buffalo currant. The best cultivated varieties are said to be the "Crandall," "Deseret," and "Jelly." It is doubtful if it will resist the dry heat of the Salton Basin.

Alkali currant (*Ribes aureum tenuiflorum* (Lindl.) Torr.). Grows in strongly saline soil in Washington, Oregon, northern California, and Nevada.

Fig (*Ficus carica*, L.).

VEGETABLES.

Jerusalem artichoke (*Helianthus tuberosus*, L.). The white variety is said to be the best for alkali soils.

Beet-root (*Beta vulgaris hortensis*).

Carrot (*Daucus carota*, L.).

Spinach (*Spinacia oleracea*, L.). (Medium alkali.)

Radish (*Raphanus sativus*, L.).

Celery (*Apium graveolens*, L.).

Celeriac (*Apium graveolens rapaceum*, DC.).

Asparagus (*Asparagus officinalis*, L.).

Onion (*Allium cepa*, L.).

Swiss chard (*Beta vulgaris cicla*).

Globe artichoke (*Cynara scolymus*, L.).

Cardoon (*Cynara cardunculus*, L.).

Tomato (*Lycopersicum esculentum*, Mill.); worth trial.

Egg-plant (*Solanum melongena*, L.). Very hardy against dry heat.

Sea-kale (*Crambe maritima*, L.).

Garden cress (*Lepidium sativum*, L.).

Roselle (*Hibiscus sabdariffa*, L.).

New Zealand spinach (*Tetragonia expansa*, Murr.).

Quinoa (*Chenopodium quinoa*, Willd.). The foliage makes a savory and wholesome greens.

STARCH FOODS.

Quinoa (*Chenopodium quinoa*, Willd.). The seeds form one of the most important foodstuffs of the inhabitants of Peru and Chile, who make a nutritious porridge of it.

SUGAR CROPS.

Sugar-beet (*Beta vulgaris altissima*).

Sugar sorghum (*Andropogon sorghum saccharatus* (L.) Kœrn).

OIL PLANTS.

Russian sunflower (*Helianthus annuus*, L.).

Niger seed (*Guizotia abyssinica*, Cass.). This plant is worth a trial on alkali soils.

FORAGE PLANTS.

Root crops:

Jerusalem artichoke (*Helianthus tuberosus*, L.). Valuable tuber for hogs. The white variety seems to be better adapted for alkali soils than the red.

Mangold-wurzel (*Beta vulgaris rapa*).

Seed crops:

Russian sunflower (*Helianthus annuus*, L.). The seeds furnish a valuable poultry food. The sunflower is reported to endure the excessive summer heat of central Australia better than any other cultivated herb tried there. The wild form of this plant (indigenous to California) has been found to tolerate easily 12,500 pounds of salts in an acre-foot at Chino.

Barley (*Hordeum vulgare*, L.).

Japanese barnyard millet (*Panicum crusgalli maximum*, Hort.).

Pasture, soiling, and hay plants:

Alfalfa (*Medicago sativa*, L.).

Saltbushes (*Atriplex semibaccata*, R.Br.; *A. leptocarpa*, F.v.M.; *A. vesicaria*, Howard; *A. kochiana*, Maiden; *A. spongiosa*, F.v.M.; *A. halimoides*, Lindl.; *A. holocarpa*, F.v.M., and *A. campanulata*, Benth.; *Kochia aphylla*, R.Br., and *K. pyramidata*, Benth.; *Rhagodia billardieri*, R.Br.; *R. parabolica*, R.Br.; *R. hastata*, R.Br., and *R. linifolia*, R.Br.; *Sclerolæna bicornis*, Lindl.).

Modiola (*Modiola decumbens*, G. Don).

New Zealand spinach (*Tetragonia expansa*, Murray).

Slough-grass (*Beckmannia erucæformis*, Host.).

Alkali tussock-grass (*Sporobolus airoides* (Torr.) Thurb.)

Alkali slender-grass (*Leptochloa imbricata*, Thurb.).

Saccaton (*Sporobolus wrightii*, Munro).

Alkali saccaton (*Panicum bulbosum*, H. B. K.).

Salt-grass (*Distichlis spicata* (L.) Greene).

Alkali lyme-grass (*Elymus salinus*, Jones).

Barnyard-grass (*Panicum crusgalli*, L.).

Japanese barnyard millet (*Panicum crusgalli maximum*, Hort.).

Switch-grass (*Panicum virgatum*, L.).

Nevada blue-grass (*Poa nevadensis*, Vasey).

Mexican salt-grass (*Eragrostis obtusiflora*, Scribn.).

Wild rye (*Elymus condensatus*, Presl.).

Meadow barley-grass (*Hordeum nodosum*, L.).

Little barley-grass (*Hordeum pusillum*, Nutt.).

Creeping bent-grass (*Agrostis alba stolonifera*).

Kaffir corn, Jerusalem corn, Durra, and Milo maize (*Andropogon sorghum sativus*, Hack.).

Egyptian corn (*Andropogon sorghum cernuus*, Kœrn).

Teosinte (*Euchlæna luxurians* (Durieu) Aschers).

Usar-grass (*Sporobolus orientalis*, Kth.).

Purslane (*Portulaca oleracea*, L.).

Bulbous-rooted foxtail (*Alopecurus bulbosus*, Huds.).

Korean lawn-grass (*Zoysia pungens*, Willd.).

Barley (*Hordeum vulgare*, L.).

Bermuda-grass (*Cynodon dactylon* (L.) Pers.).

Quitch-grass (*Agropyron repens*, Beauv.).

Johnson-grass (*Andropogon halepensis* (L.) Brot.).

The three last-named grasses (Bermuda-grass, Quitch-grass, and Johnson-grass) are liable to become terrible weeds in cultivated ground, and should not be planted where there is any danger of their spreading among orchards or cultivated crops, nor, in fact, in any place which is not to be given up *entirely and permanently* to pasture.

Browsing shrubs:

Tea-tree (*Leptospermum lanigerum*, Smith).

Myalls (*Acacia homalophylla*, Cunn., and *A. pendula*, Cunn.).

Shrubby saltbushes (*Atriplex nummularia*, Lindl.; *A. pamparum*, Griseb.; *Rhagodia spinescens inermis*).

PAPER-MAKING MATERIALS.

Esparto-grass (*Stipa tenacissima*, L.).

Albardin (*Lygeum spartum*, L.).

SHADE AND ORNAMENTAL TREES AND SHRUBS.

Kœlreuteria paniculata, Laxm.

Acacia pendula, Cunn.

Acacia homalophylla, Cunn.

Albizzia lophantha, Benth.

Albizzia lebbek, Benth.

Canary date-palm (*Phœnix canariensis*, Hort.).

Washington palm (*Washingtonia filifera*, Wendl.).

Oriental sycamore (*Platanus orientalis*, L.).

Manna gum (*Eucalyptus viminalis*, Labill.).

Peppermint gum (*Eucalyptus amygdalina*, Labill.).

Red gum (*Eucalyptus rostrata*, Schlecht.).

Yate tree (*Eucalyptus cornuta*, Labill.).

It should be borne in mind that these several plants are not equally tolerant of alkali, and that local experimentation is necessary in order to determine the adaptation of each one to local conditions.

TOLERANCE OF VARIOUS CROPS FOR ALKALI SALTS.

The subjoined table, originally published in Bulletin No. 133 of this Station, is of interest in connection with the discussion of the availability of the Salton Basin lands for cultural purposes. For comparison with other publications it should be remembered that the calculation of the "pounds per acre," most readily understood by farmers, is based on the estimated weight of an acre-foot of soil at four millions of pounds. Hence, one per cent is equal to 40,000 pounds; one-tenth of one per cent, 4,000 pounds. It will be noted that the *total of salts* alone is but a very rough criterion of the possibilities of culture, on account of the very different effects of the several compounds on plants. The sulfates (of potash, soda, and magnesia) are the least injurious, and happily predominate widely in the Salton Basin. Carbonate of soda, though very injurious as such, is easily transformed into the bland sulfate by dressings of gypsum. Common salt is really the worst ingredient.

Highest Amount of Alkali in Which Fruit Trees Were Found Unaffected.

Arranged from highest to lowest. Pounds per acre in four feet depth.

Sulfates (Glauber Salt).		Carbonate (Salsoda).		Chlorid (Common Salt).		Total Alkali.	
Grapes	40,800	Grapes	7,550	Grapes	9,640	Grapes	45,760
Olives	30,640	Oranges	3,840	Olives	6,640	Olives	40,160
Figs	24,480	Olives	2,880	Oranges	3,360	Almonds	26,560
Almonds	22,720	Pears	1,760	Almonds	2,400	Figs	26,400
Oranges	18,600	Almonds	1,440	Mulberry	2,240	Oranges	21,840
Pears	17,800	Prunes	1,360	Pears	1,360	Pears	20,920
Apples	14,240	Figs	1,120	Apples	1,240	Apples	16,120
Peaches	9,600	Peaches	680	Prunes	1,200	Prunes	11,800
Prunes	9,240	Apples	640	Peaches	1,000	Peaches	11,280
Apricots	8,640	Apricots	480	Apricots	960	Apricots	10,080
Lemons	4,480	Lemons	480	Lemons	800	Lemons	5,760
Mulberry	3,360	Mulberry	160	Figs	800	Mulberry	5,760

Other Trees.

Kölreuteria	51,040	Kölreuteria	9,920	Or. Sycamore	20,320	Kölreuteria	73,600
Eucal. am.	34,720	Or. Sycamore	3,200	Kölreuteria	12,640	Or. Sycamore.	42,760
Or. Sycamore.	19,240	Date Palms	2,800	Eucal. am.	2,960	Eucal. am.	40,400
Wash. Palms.	13,040	Eucal. am.	2,720	Camph. Tree.	1,420	Wash. Palms.	15,280
Date Palms	5,500	Wash. Palms	1,200	Wash. Palms	1,040	Date Palms	8,320
Camph. Tree.	5,280	Camph. Tree.	320			Camph. Tree.	7,020

Small Cultures.

Saltbush	125,640	Saltbush	18,560	Modiola	40,860	Saltbush	156,720
Alfalfa, old	102,480	Barley	12,170	Saltbush	12,520	Alfalfa, old	110,320
Alfalfa, young	11,120	Bur Clover	11,300	Sorghum	9,680	Alfalfa, young	13,120
Hairy Vetch	63,720	Sorghum	9,840	Celery	9,600	Sorghum	81,360
Sorghum	61,840	Radish	8,720	Alfalfa, old	5,760	Hairy Vetch	69,360
Sugar Beet	52,640	Modiola	4,760	Alfalfa, yo'ng	760	Radish	62,840
Sunflower	52,640	Sugar Beet	4,000	Sunflower	5,440	Sunflower	59,840
Radish	51,880	Gluten Wheat	3,000	Sugar Beet	5,440	Sugar Beet	59,840
Artichoke	38,720	Artichoke	2,760	Barley	5,100	Modiola	52,420
Carrot	24,880	Lupin	2,720	Hairy Vetch.	3,160	Artichoke	42,960
Gluten Wheat	20,960	Hairy Vetch.	2,480	Lupin	3,040	Carrot	28,480
Wheat	15,120	Alfalfa	2,360	Carrot	2,360	Barley	25,520
Barley	12,020	Grasses	2,300	Radish	2,240	Gluten Wheat	24,320
Goat's Rue	10,880	Kaffir Corn	1,800	Rye	1,720	Wheat	17,280
Rye	9,800	Sweet Corn	1,800	Artichoke	1,480	Bur Clover	17,000
Cañaigre	9,160	Sunflower	1,760	Gluten Wheat	1,480	Celery	13,680
Ray Grass	6,920	Wheat	1,480	Wheat	1,160	Rye	12,480
Modiola	6,800	Carrot	1,240	Grasses	1,000	Goat's Rue	11,800
Bur Clover	5,700	Rye	960	White Melilot	440	Lupin	11,200
Lupin	5,440	Goat's Rue	760	Goat's Rue	160	Cañaigre	9,360
White Melilot	4,920	White Melilot	480	Cañaigre	80	Ray Grass	6,920
Celery	4,080	Cañaigre	120			White Melilot	5,840

JANUARY CROP REPORTS FROM ACTUAL SETTLERS.

Reports have been received from sections 19 and 20, in township 14 south, range 15 east, sections 29, 32, and 33, in township 16 south, range 14 east, and on land adjoining the town of Imperial on the south. They show apparent success, during the past season, in growing alfalfa, sorghum, barley, millet, Kaffir corn, and watermelons, with a few lesser tracts of garden vegetables. As an illustration of the tone of these reports, we present the following extract from a letter received from Thomas Beach, Calexico; a region which, however, is outside of the worst clay and alkali belts:

"Between the last of June and middle of August of last year I put in about 325 acres of sorghum, 30 of millet, 20 of field corn, 25 of Kaffir corn, 2 of melons, 1 of cotton, and 1 acre of pumpkins. The sorghum was watered six times and the others about four. The former gave about 5 tons per acre, and the millet yielded 2 tons; the corn did not do as well. I raised some Rocky Ford melons from seed ripened the same year at Indio, and can say that I never tasted better; the same is true of watermelons and pumpkins. The ground took water well, and during the summer months I was able to disc it three days after flooding. I now (January 28th) have barley 2 feet high that has been watered but twice; some alfalfa I sowed on the 20th of September is up 6 or 8 inches in height, with roots a foot long and has had but two irrigations."

These reports do not in any sense contradict the facts stated in the earlier pages of this report; for it will be noted in the first place that these are, in nearly every case, *alkali-resistant crops.*

Upon inspection of the maps and tables it will be further seen that, in general, the first foot of soil does not carry the heavy percentage of alkali which exists at a depth of two to three feet. An irrigation, either just preceding or just following seeding, would tend to temporarily reduce the alkali in this upper foot even below the amount shown in the tables, and below the maximum tolerance of the essentially alkali-resistant plants named above; and probably also below that for many of much less resistant kinds. There is little doubt that, *at the outset*, most plants climatically adapted could be started with more or less success under the common methods of irrigation. These early results can only be taken as indicating that the alkali in the top foot *at this time and in those localities* was not sufficiently strong to interfere seriously with the germination of seed—retardation possibly excepted.

The reports can not, however, be taken as indicative of what may be expected after surface irrigation has been practiced for a few years; for such treatment is sure to result in the rise of alkali to such an extent as to cause serious injury to the crop and consequent financial loss to the grower.

Mention has already been made of the alkali-resistant nature of these crops, except millet and watermelons. In the case of the former, which is closely related to sorghum, it may be expected to be quite resistant, although no figures are at hand touching upon the matter; the watermelon is essentially a desert plant, related plants being indigenous to the African deserts. The growth of these crops in these localities simply adds weight to the evidence that these plants are quite tolerant of alkali.

People should not be deceived by a rank growth of plants in arid regions, unless the characteristics of such plants be definitely known; for the very fact of the existence of alkali is evidence of intrinsic fertility of the soils, and crops are well known to have a luxuriant growth on such lands, provided only that the saline matter is not present to such an extent as to approach the limit of tolerance of the crops grown.

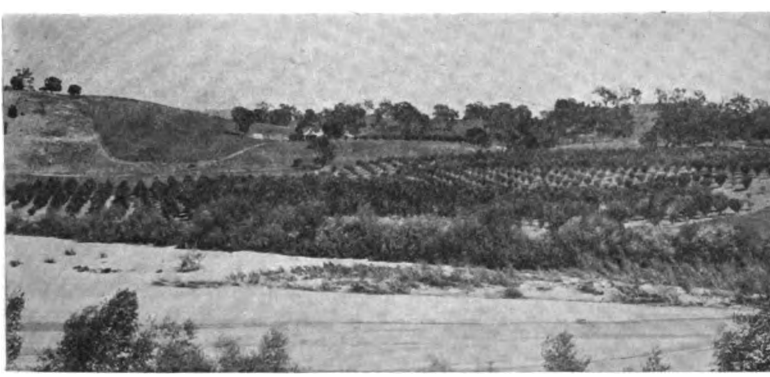
Notwithstanding the present success with the alkali-resistant crops named, residents are urged to adopt the methods laid down in this publication as those which alone may reasonably be expected to give immunity from alkali damage for any considerable length of time.

UNIVERSITY OF CALIFORNIA PUBLICATIONS

UNIVERSITY OF CALIFORNIA—COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION

EXPERIMENTS WITH DECIDUOUS FRUITS AT AND NEAR THE SOUTHERN COAST RANGE SUB-STATION, PASO ROBLES, FROM 1889 TO 1902

By CHARLES HOWARD SHINN
Inspector of Experiment Stations



STEINBECK ORCHARD, NEAR TEMPLETON

BULLETIN No. 141

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BENJAMIN IDE WHEELER, Ph.D., LL.D., President of the University.

EXPERIMENT STATION STAFF.

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E. J. WICKSON, M.A., Horticulturist.

W. A. SETCHELL, Ph.D., Botanist.

R. H. LOUGHRIDGE, Ph.D., Agricultural Geologist and Soil Physicist. (Soils, Alkali.)

C. W. WOODWORTH, M.S., Entomologist.

M. E. JAFFA, Ph.B., M.S., Assistant Chemist. (Foods, Fertilizers.)

G. W. SHAW, Ph.D., Assistant Chemist. (Soils, Sugars.)

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Bulletins and reports of this Station will be sent free to any citizen of the State, upon application.

EXPERIMENTS WITH DECIDUOUS FRUITS AT AND NEAR THE SOUTHERN COAST RANGE STATION.

The purpose of this bulletin is to give a clear and exact account of experiments conducted by the California Station during a period of thirteen years in order to ascertain the possibilities of deciduous-fruit culture upon the substation tract east of the Salinas River, near the town of Paso Robles, and upon similar soils in that and other districts of the Southern Coast Range.

So far as the Station and its workers are concerned, these results are practically final, excepting as otherwise stated in the following pages; and those who propose to plant orchards on similar soils, under similar climatic conditions, can take the conclusions reached in this bulletin as those of thirteen years' experience, with much expenditure of time and money, and a very careful study of a large area of contiguous country.

The problem in regard to orchards presented to an experimenter in a given district is always a complex one, especially if that district, while untried, is under rapid industrial improvement. There is, then, every possible temptation offered to the community to become very enthusiastic over all sorts of new and promising crops, of which fruit, one of the great resources of old and long-settled regions, naturally receives immediate attention. Orchard planting in such cases far outruns the slow but steady efforts of the experimenter, and often duplicates his failures or successes before he can reach, much less publish, trustworthy results. Meanwhile the work of the experimenter goes on, directed to the ascertainment of certain definite results. He wishes to know what fruits can be made commercially successful in the district, what fruits can be grown in a small way for family use, and what fruits should be entirely discarded. He must exhaust his utmost resources of horticultural experience to give these fruits complete tests under different treatments; he must analyze the causes of success or failure, so as to be able to apply the results of these experiments upon one or several plots of ground to much larger areas, and thus to furnish a more or less trustworthy guide for investors in years to come.

It is always best for would-be orchardists that the results of a long series of investigations be stated with entire frankness, and exactly as they impress the experimenters, who have no financial interests involved. If further experiments, in after years, modify any adverse conclusion, enlarging the field of successful culture of some of the fruits herein named, it is nevertheless better that the case against them should have been plainly and fully stated.

The planting of fruit trees on unsuitable soils, or where other conditions are strongly adverse, causes great economic loss. In the end, the nurserymen who grew the trees, the local agents who sold them, the land owners, the land dealers, and the entire community are severe sufferers. Errors in respect to annual crops are easily remedied, but errors in regard to crops which it requires several years to bring to bearing age, or, as in such cases as the present, nearly one-third of an average life-time to test thoroughly, are highly expensive. When a region is rapidly passing from pastoral to agricultural conditions, no foresight can prevent such mistakes, for time, patience, close observation, and carefully conducted tests are necessary to determine the natural limitations of any district. Whenever those limitations have been correctly outlined, they must be recognized and thereafter dealt with as accepted facts, and the community must develop its industries accordingly.

General View of the Region.

One of the most striking features of the Southern Coast Range is the broken chain of valleys, high plains, and passes that form a line of separation between the western and the eastern sides. Along this succession of narrow gateways and broader levels, the Missions of Soledad, San Antonio, San Miguel, and San Luis Obispo were founded and great Spanish ranches came into existence; the railroad of to-day follows much the same route up the Salinas and south to Lompoc.

The country which has been studied lies almost altogether east of this medial line along the Salinas, and occupies portions of San Benito, Monterey, and San Luis Obispo counties. It is in shape an irregular oval, nearly forty miles long by twenty wide, extending south-east and north-west. While extremely diversified in appearance, rising into great peaks, spreading out into broad, rolling plains, or narrowing into winding cañons, it has a unity in soil, climate, and larger agricultural problems that is seldom found in so large an area of hill country.

Upon a preliminary survey, one may begin as far north as La Gloria Valley and the ridges about Cholone Peak in Monterey, and thence come south past the wide channels of the San Lorenzo River and past Slack's Cañon and Indian Valley in the rugged south-eastern corner of Monterey, where numerous tributaries of the Estrella take rise. Such streams as the Gaviota, which reaches the Salinas at San Ardo, the lesser creeks flowing west to Sargent and Bradley, and the larger water-courses of Indian, Vineyard, San Jacinto, Ranchito, Cholame, Palo Prieto, Antelope, and others are surprisingly alike in appearance and surroundings. The still larger Estrella and its continuation, San Juan Creek flowing down from the high Carisa region, the winding Huerhuero, and even the upper Salinas itself, extending upward past San Ardo, San Miguel, Paso Robles and other thriving towns to Salsipuedes, Rinconadas, and the mining districts, are all of the same type. All are streams of more or less intermittent winter flow; many of them are non-periodic, sometimes for several seasons having no floods and in summer disappearing from sight. Their beds are broad, sandy channels, not very different in appearance from the well-known "washes" of Southern California streams but comparatively free from pebbles. Along these streams are narrow bottoms, then higher benches, sometimes on several levels, on which irrigation from the streams is more or less practicable, but the total area of these lands is small. The valleys and rolling plains east of the Salinas, such as Elkhorn, Carisa, Cholame, Estrella, Huerhuero, Avalan, Long, Antelope, Wild Horse, and, away over on the San Joaquin side, McClures and Kettleman, include very diverse regions, but are all alike in having a more or less fluctuating rainfall, severe frosts, and soils which, though sometimes extremely fertile, are mainly granitic sands and gravels derived from the granite hills about the heads of the Estrella, San Juan, and Salinas. The brownish or blackish soils are derived from the clays, clay-stones, bituminous shales, and various associated rocks of this much-varied region. The Bradley plains on the west side of the Salinas, north of San Miguel, present much the same features as the eastern plains, but have a better soil, derived from the Santa Lucia range, lying west.

My own observations of orchards, made at various times for twenty-five years, have covered the greater part of Monterey and San Luis Obispo, as well as portions of San Benito. My closer studies in recent years have taken me as far south as San José Valley, east almost to La Panza, west to the summits of the Santa Lucias, north to Kings City, and northeast to Slack Cañon. The great ranches of the past have been subdivided and sold. The country is everywhere being utilized for both pastoral and agricultural purposes. As a whole, it possesses much fertile land, many small but prosperous communities, and growing resources. The pioneers have now learned better than ever before the possibilities as well as the limitations of their soils and their climate. They even find it possible now to produce crops with a much smaller rainfall than was formerly thought needful, and they are making homes upon lands once considered fit only for pasturage. Such towns as Creston, Cholame, and Shandon have been founded upon old cattle-ranges.

SOIL OF THE SUB-STATION.

Before the sub-station was established the Director made an examination of the soils of the region and more especially of the particular tract chosen. This tract has been mapped and described in previous station reports. It is therefore sufficient to say here that it covers twenty acres lying in a parallelogram 495 feet wide and 1720 feet long. The southern part of the tract is a light sand mixed with white hornstone, quartz, feldspar, and claystone debris and containing but a small amount of clay. Most of this light soil is underlaid by a deep sandy "hardpan"* extending from a point one to three feet below the surface downwards to a point six to ten feet lower. Below the hardpan is a sandy soil sometimes containing more clay than the surface

* The hardpan underlying the soils of the station is a grayish mass of coarse grains not bound together by any cementing substance (except in spots where there is a calcareous cement) but formed into a compact rock-like mass by the peculiar wedge-shape structure of the individual grains. It is therefore a mechanical instead of a cement hardpan. A mechanical analysis of a part taken from the third foot of the hardpan column shows the following percentages of fine and coarse grains:

PHYSICAL COMPOSITION OF HARDPAN.

Diameter of grains.		*Material.*	*Per cent.*
2.	*mm.*	Very coarse grits	6.9
2.—1.	"	Coarse grits	12.0
1.—0.5	"	Medium grits	13.5
.50—.30	"	Very coarse sand	7.5
.30—.16	"	Coarse sand	13.8
.16—.12	"	Medium sand	5.1
.12—.072	"	Fine sand	4.9
.072—.047	"	Coarse silt	6.5
.047—.036	"	Coarse silt	8.1
.036—.025	"	Medium silt	4.8
.025—.016	"	Fine silt	0.8
.016—.0023	"	Finest silt	9.8
.0023—	"	Colloidal clay	5.8
			99.5

The percentage of the coarse material is very large, while that of clay and fine silts is very small. There would seem to be an amount of the latter just sufficient to fill the spaces between the large grains and aid in the firming of the mass, rendering it practically impervious to water; and wherever it underlies stream beds, dangerous wet quicksands remain till late in the season. The hardpan yields readily to water, *i.e.*, when a detached lump *above ground* is wetted it quickly falls apart as a mushy mass; but *in situ*, when water is applied to it, while it softens gradually it again becomes firm and compact on drying because of the undisturbed position of its component grains. Even when shattered by blasting, if the fragments are allowed to remain in the hole, they again in the course of time become as firmly compacted as before, thus showing that this is not a cemented hardpan. Hence it was not recognized as a serious obstacale.—R. H. L.

soil, but sometimes gravelly. The back portion of the tract is mostly a gray, silty soil mingled with a good deal of clay, and in portions underlaid by black adobe, breaking in places into the well-known "hog-wallow" or uneven surface common in this region. Between these soils and the sandy hardpan is a swale, or depression across the tract, where the soil is a fine silt with little clay, baking hard in summer, and boggy in winter. Sandy hardpan, gray and heavier, brown and black adobe soil, and fine-silted swale-soil are all remarkably characteristic of a great deal of the region east of the Salinas.

The table on the following page gives the analyses of the soils represented on or near the sub-station tract, taken to a depth of one foot.

The Director, in discussing these soils, in 1889, drew attention to the low moisture absorption in No. 1147, to the small supply of humus and lack of iron in No. 1126, to the necessity of drainage and good tilth of the swale soils (whose value is on many farms much neglected), to the very high contents of lime, potash, humus, and phosphoric acid in the black adobe, and to the lesser value of the brown adobe. The actual use of these soils since 1889 has amply borne out these deductions.

History of Orchard to 1894.

Beginning work.—In the spring of 1889 about four hundred varieties of deciduous fruits were planted, including nuts. The list was largely made up from those kinds most successful in Alameda and Santa Clara counties. The trees were cut to three feet, to allow for future trunks of eighteen inches. The collection was as follows: Apples, 90 varieties; cherries, 38 varieties; pears, 65 varieties, besides some seedlings and Japanese stocks; plums and prunes, 70 varieties; peaches and nectarines, 70 varieties; almonds, 10 varieties; apricots, 20 varieties; quinces, 7 varieties; walnuts, pecans and filberts, 14 varieties; besides the preceding, figs, olives, Japanese persimmons, and mulberries were planted. Nearly all of these trees made a fair start; the apples, cherries, and peaches did best. The plums did poorly. All the trees grew best on the granitic, sandy soil, as it was new and the roots had not yet reached the hardpan.

From 1889 to 1894.—During the four years to the winter of 1893–94 much of this orchard gave promise of being of considerable value. The trees were growing very well in most cases, the roots had not reached the hardpan, the rainfall was fairly good; the orchard had not yet reached the point of greatest stress. The difficulties were chiefly due to sunburn, against which the trunks were protected by wraps and shakes; to the flat-head borers (*Dicera divaricata*), hundreds of which

Analyses of Soils of the Southern Coast Range Sub-station.

	Granite on hardpan. No. 1147.	Gray, silty soil. No. 1126.	Swale Soil. No. 1148.	Black adobe on hill. No 1123.	Brown adobe. No. 1149.
Coarse materials > 0.5 mm diameter	39.5	20.5	15.3	20.00	13.52
Fine earth	60.5	79.5	84.7	80.00	86.48
Analysis of Fine Earth.					
Insoluble matter	85.12 } 90.69	87.26 } 92.45	81.79 } 90.31	55.43 } 73.38	57.69 } 78.67
Soluble silica	5.57 }	5.19 }	8.52 }	17.95 }	20.98 }
Potash	.68	.40	.60	.77	.70
Soda	.31	.35	.27	.64	.18
Lime	.34	.26	.41	5.97	1.09
Magnesia	.37	.32	.45	1.03	1.04
Br. ox. of manganese	.04	.03	.04	.05	.04
Peroxide of Iron	3.83	1.68	3.26	3.43	4.39
Alumina	1.74	2.93	2.80	5.99	9.16
Phosphoric acid	.07	.02	.06	.44	.08
Sulphuric acid	.03	.05	.01	.07	.01
Carbonic acid	....	....	....	3.25	....
Water and organic matter	2.19	1.86	2.12	5.25	4.67
Total	100.29	100.35	100.33	100.27	100.03
Humus	.66	.55	1.16	1.25	.47
Ash	.79	.86	1.28	.47	.21
Available phos. acid	....	.02	....	.05	.03
Silica	....	....	....	....	....
Hygroscopic moisture (absorbed at 15° C.)	1.84	2.50	3.43	10.22	11.14

were destroyed by a sharp wire or cut from the trunks; and to gummosis which in a few years showed on the cherries and plums.

Apples.—In 1890 these grew well. In 1891 a few kinds began to bear fruit of good quality, and the apple was considered at home here. In 1892 and 1893 some trees showed stunted growth (*i. e.* had reached hardpan). By 1893 some root-knot showed on a number of trees. Those apples which were five years old in a few cases covered a circle of seven feet in diameter with their branches and were seven or eight feet high.

Pears.—In 1891 an avenue of pears was planted where the figs had failed on account of frost. The pears grew very well on the heavier soils. By 1893, the largest pear trees were over ten feet high and each covered a circle of seven feet in diameter. There were eighty-six grafted trees (60 varieties) and twenty-five Japanese seedlings. Pears on the granitic soil were poor.

Almonds.—These made excellent growth during these four years, considering the soil. In 1891 five varieties bore; three were frosted. Other almond crops along the Salinas escaped. There were well-founded hopes of developing an almond industry, particularly in the Santa Lucia range west of the river. In 1892 and 1893 the almonds bore well, excepting Commercial, which was frosted. The heaviest crop was ten pounds per tree. The quality of the nuts was excellent. Ten varieties were in bearing by 1893.

Cherries.—The growth of these trees was weaker by 1890, and by 1891 the trunks of the trees were badly cracked by sun-burn. By 1892 it was evident that the extreme dryness of the atmosphere and the light rainfall rendered this district unfit for the cherry. In 1893 the largest tree was seven feet in spread of branches, but most of them (then over four years planted) were but five feet across. Forty-one varieties were represented, eight of which bore in 1893. The crops were small and the trees unhealthy.

Apricots.—In 1890, these trees continued to thrive better on the light granitic than on the heavier soils. They died in many cases in the swale. The plum stock proved poor and stunted; the apricot stock was better. In 1891 very uneven growth of all the apricots was noted and some branches died back. By 1893 the largest tree spread over a circle of ten feet in diameter. The trees on hardpan had begun to suffer seriously. Eight of the eleven varieties of bearing age first yielded small crops in 1893.

Peaches and Nectarines.—In 1890 some trees bore fruit. Those on plum stock were stunted and poor. In 1891 forty varieties bore from one to fifty pounds of excellent fruit per tree. Twenty-one varieties had their blossoms frosted. There were heavy frosts in January, February, March, and April. The prospects for successful peach and nectarine culture appeared very bright in 1892–4, when out of seventy-three varieties of peach and nine of nectarines, nearly all bore crops ranging from eight to 100 pounds per tree. Thirty seedlings were also coming into bearing. The blossoming and ripening periods of the different varieties of peaches and nectarines showed very considerable variations from the normal times in other districts, and in relation to each other. As the roots, about 1893, began to reach hardpan, the blossom periods and ripening periods of all these stone fruits became irregular and abnormal. This was more noticeable with these fruits than with plums or cherries, apples or pears.

Plums and Prunes.—The growth of these trees was greatly improved in 1890 by the partial draining of the swale. The Japanese plums did well, Botan doing best, but all promising success. In 1892 and 1893 the plums on hardpan began to fail. The yield per tree on better soil was from six to forty pounds. The European plums began to bear quite well, but the Japanese varieties continued to be valuable. The prunes did but poorly. The best five varieties of plums were Botan, Burbank, Kelsey, Imperial Gage, and Rivers' Early Prolific. Five-year-old-trees covered a circle of six feet in diameter. Myrobalan seedlings were eight feet across.

Quinces.—The quinces suffered much from the dry atmosphere and the poor soil, and had nearly ceased growth by 1893. The few fruits borne were very small and worthless.

Figs.—In 1890 the figs were badly frozen in the swale, but trees higher up escaped. In 1891 and 1892 the trees were again frozen, and to the ground. A few varieties by 1893 seemed to have recovered partially. Angelique, Black Bourjasotte, and White Ischia bore some fruit at the main-crop season. More figs were planted on higher ground.

Olives.—The olives made an excellent start, most varieties growing well till the spring of 1894. Atroviolacea was particularly hardy. Nevadillo Blanco proved too tender. Oblonga, Rubra, and Pendulina bore fruit in 1892. It appeared evident, however, that with care in selection of varieties and location, the olive would thrive in this district as the growth of all the hardier sorts between 1889 and 1893 was satisfactory, considering the lightness of the soil.

Walnuts, Chestnuts, Pecans, etc.—Of nine varieties of walnuts planted in 1889, only three, and those very poor specimens, were left in 1893. The collection of chestnuts was equally a failure. One pecan tree remained, but was worthless and soon perished.

A collection of Japanese persimmons proved entirely unsuited to this locality.

A large collection of mulberries was planted in 1889 and nearly all throve for a few years, making strong trees covering circles fifteen feet in diameter by 1893. Nagasaki was the best grower, with Alba and Russian nearly as good.

Grapes.—The large vineyard, containing all the leading varieties of table and wine grapes, grew and bore quite well for about three years until the roots reached hardpan. Many small vineyards were planted in the district, and appeared to prosper on similar soil. The vineyards elsewhere receive notice in subsequent paragraphs. So well did the vineyard grow, and such excellent fruit did it produce between 1890 and 1894 that the late Adolph Sutro, who visited the sub-station in 1893, regretted his failure to buy one of the big ranches east of the river and plant it all out in wine grapes.

Conclusions.—To sum up this period of four years, the sub-station had reason by the winter of 1893–4 to believe that with care, apples, pears, Japanese and some other plums, peaches and nectarines, olives and mulberries as well as grapes would succeed here. The temporary success of the almond it did not seem reasonable to expect would continue, but hopes for the other fruits, together with all the inferences therefrom, appeared justifiable.

Orchard History, 1894–1900.

In the winter of 1893–4 the entire district suffered from drought. The tree-roots of this particular orchard had now reached hardpan wherever such soil underlaid the surface within two or three feet, and had spread widely out upon that hardpan. The trees in some cases were also beginning to bear; in others were approaching a full bearing age. The total rainfall at the sub-station from October, 1893, to July 1st, 1894, was 5.70 inches, accompanied in spring by drying winds and severe frosts. The actual rainfall of value to crops, not mere scattering showers in May and June, was but 3.68 inches. Thorough cultivation and pruning maintained the entire orchard alive, and some growth was made.

From this season, however, dates the beginning of the destruction of that part of this deciduous fruit orchard which was planted on the granite soil underlaid by hardpan, and the accompanying illustrations show clearly the nature and effect of the root difficulty. The rainfall of 1895–6 was 13.14 inches, but the season was windy and frosty, so that the orchard again suffered. In 1896–7 there was an excellent season with nearly 18 inches of rain, but 1897–98 was one of the worst on record, the rainfall being but 4.75, and badly distributed.

Apples.—Some growth was made on one-third of the trees. No fruit was yielded in 1894 or 1898. The crop of 1895 ranged from five to sixty pounds a tree and 27 varieties bore. In 1897 and 1899 the crop on about as many varieties ranged from five to forty pounds a tree. The fruit was small and poor, and lacked juice. The apples now showed, as had the peaches in former years, great variations in dates of blossoming and of ripening fruit. There were no winter apples here, all the late keepers of other districts ripening before November 1st.

Pears.—The holding power of these trees, which were, however, as a rule on heavier soil, was very satisfactory. In 1894 the Japanese seedlings bore fruit; in 1895 eight European varieties bore; in 1896 the crop was small, owing to late frosts; in 1897, 21 varieties bore from one to fifty pounds per tree; in 1898 and subsequent years the pears did very well. Many varieties showed remarkable variations in times of ripening from those observed in other parts of California. The quality of the pears grown on all soils here was very high. On hardpan the fruit was small and knotty, but still of good flavor; on the heavier soil of the swale and beyond, it was of great excellence. The largest tree was fourteen feet high.

Almonds.—The largest almond tree, by 1900, was sixteen feet high, and ten feet in spread of branches, with a trunk diameter of ten inches (variety IXL; age twelve years). The photograph (Plate 1)

PLATE 1
ALMOND ORCHARD

shows the almond orchard as it appeared in 1900. Another photograph (Plate 2) shows the root system of one of the almonds, a twelve-

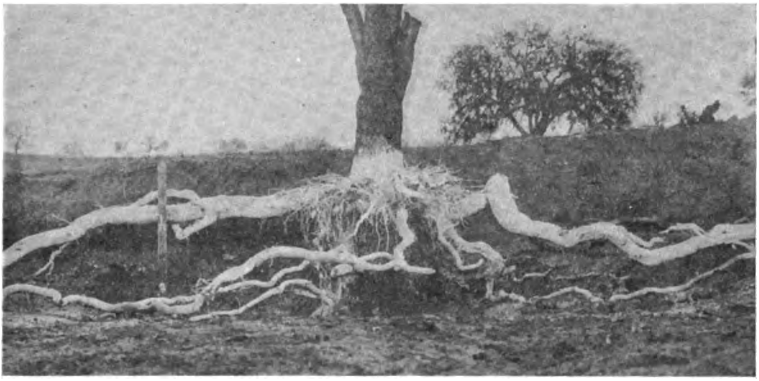

PLATE 2
ALMOND ROOTS ON HARDPAN

year-old seedling, illustrating the extent to which even the almond was forced to grow on the surface. Yet, as the photograph shows, some roots in the center really succeeded in penetrating the hardpan. These central roots were unable to pierce clear through to the substrata, but they helped to maintain the tree. During this whole period—1894–1900—the almond crop was practically a failure, owing to frosts. The almond did not prove profitable anywhere in this district; many orchards, even west of the river, in the foot-hills, were removed.

Cherries.—There was no yield worth mentioning during this period. The trees suffered more than ever from gummosis. The few fruits were of excellent quality. Mahalebs did little better than Mazzards, bearing more, but suffering as much from the unsuitable soil and climate. The late frosts destroyed most of the blossoms.

Apricots.—All varieties practically lost their entire crops from the late frosts; a few apricots ripened in 1897 and 1899. The ordinary varieties of commerce are useless here, and the only chance of success lies in the hardier but less valuable Russian and half-wild types. All the apricots on hardpan succumbed.

A typical apricot tree on hardpan is shown in the illustration (Plate 3). The variety is Smith's Triumph, ten years planted, height ten feet. This was the best apricot tree on this soil. During its entire life it has not yielded ten pounds of fruit. The root system of an adjoining tree of the same age and variety is also shown (Plate 4) and it illustrates the entire lack of penetrating power of the roots.

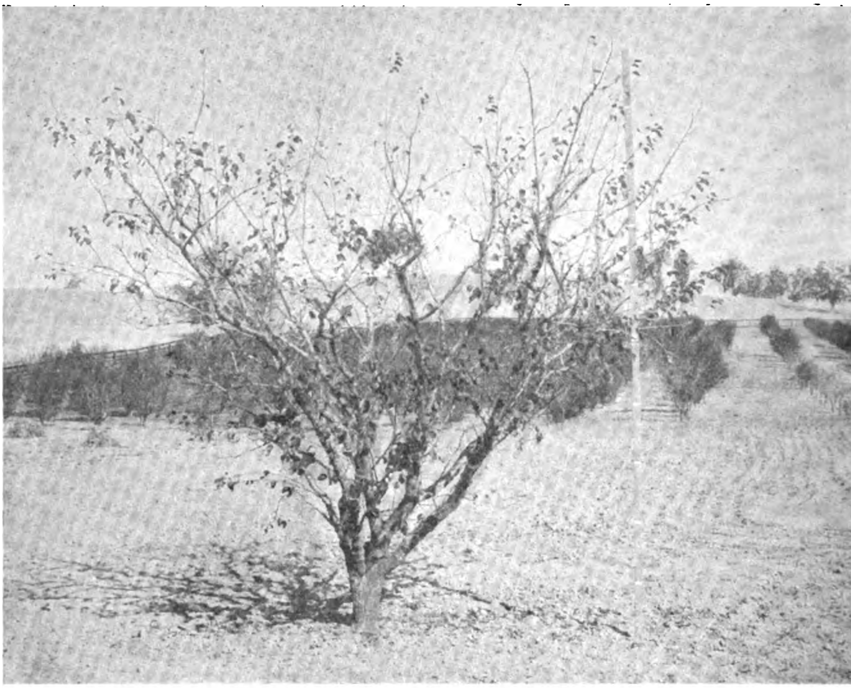

PLATE 3
APRICOT TREE ON HARDPAN

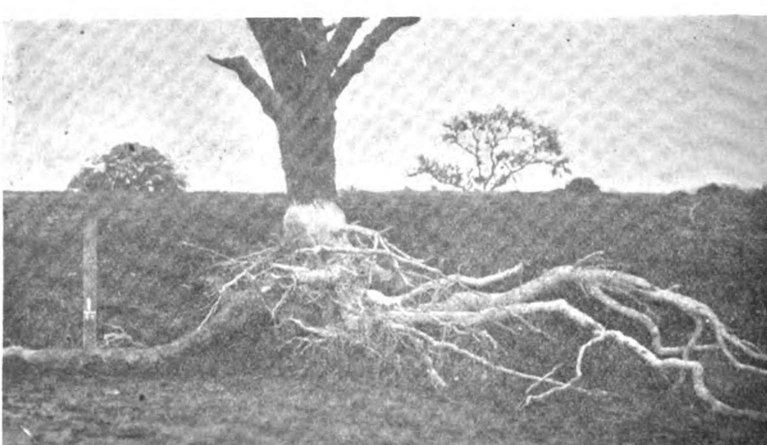

PLATE 4
ROOT SYSTEM OF APRICOT ON HARDPAN

The area of soil drawn upon by these apricot roots above the hardpan was less than 475 cubic feet. They seemed to lose their power of extension beyond seven or eight feet from the base of the tree. In a normal orchard with a deep soil the roots of an apricot tree may spread through upwards of 2000 cubic feet.

Peaches and Nectarines.—All additions made were of the hardier sorts. The trees on hardpan failed rapidly and the greater part were removed. In 1894, 1896, 1897, and 1898 the crop was practically destroyed by frost. In 1895 forty-one varieties bore well and twenty-five lost their crops. There was never much curl-leaf here. The trees on all soils showed gummosis, and much root-knot. On the hardpan they became very unhealthy, portions of the branches died back, and they blossomed and leaved out at irregular intervals. The nectarines appeared to withstand adverse conditions a little longer than the peaches. The best peaches as regards size and quality were the very early half-clings, such as Briggs's May; the later peaches lacked juice and size. There was quite a crop in 1897 of peaches and nectarines.

The peach is a very important fruit in this district and gives great satisfaction in many places west of the river. East of the river, on good soil, peach trees bear perhaps two years out of three, and in sheltered locations may do better. The accompanying illustration (Plate 5) of peaches and nectarines on hardpan shows plainly the

PLATE 5
PEACH AND NECTARINE ORCHARD ON HARDPAN

failure of these trees under such conditions. Such trees were no larger at twelve years of age than they had been at three—and bore less fruit. They never paid for cultivation. The photograph of the root system (Plate 7, page 17) still further illustrates the trouble. The Sellers' Cling in the picture was cut back in the drought year of 1894 and had to be protected against sunburn. All of nearly a hundred peach and nectarine trees taken out showed trunks and roots similar to those of this Sellers' Cling. The renewal of the tops was very fair, but many trees showed immense crown knots, as shown in the illustration (Plate 6).

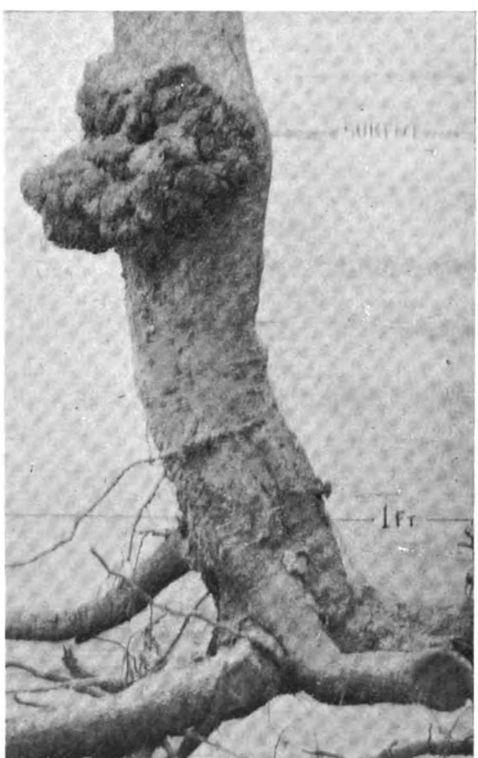

PLATE 6

CROWN KNOT ON PEACH

Plums and Prunes.—During this period the plums and prunes, which were nearly all on hardpan, failed badly and many were taken out. The late frosts destroyed both the European and the Japanese plums in 1894 and 1896, and the Japanese in 1895 also. In 1897 and

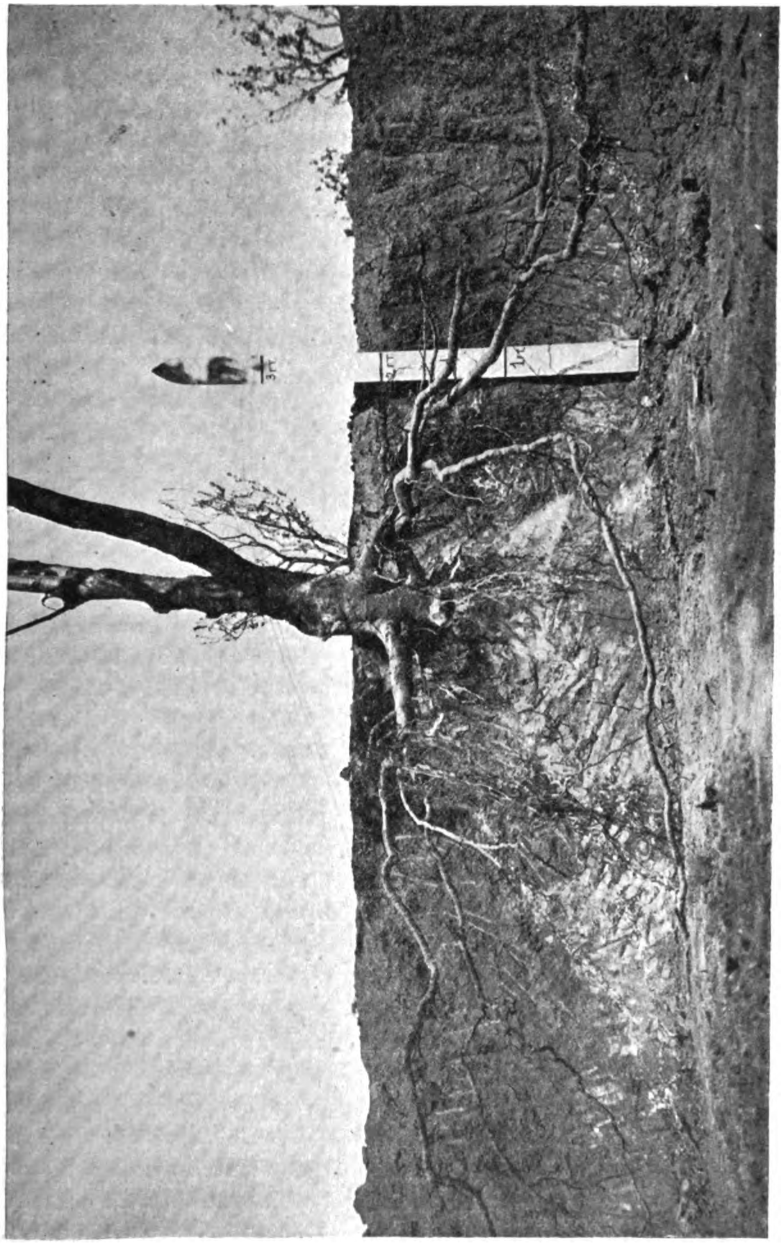

PLATE 7
PEACH TREE ON HARDPAN

1898 the Japanese types again did better than for several years previous. Burbank, Kelsey, Botankio, and Imperial Gage did very well. The new American plums, such as Milton and Hammer, withstood the late frosts. The Myrobalan bore nearly every year.

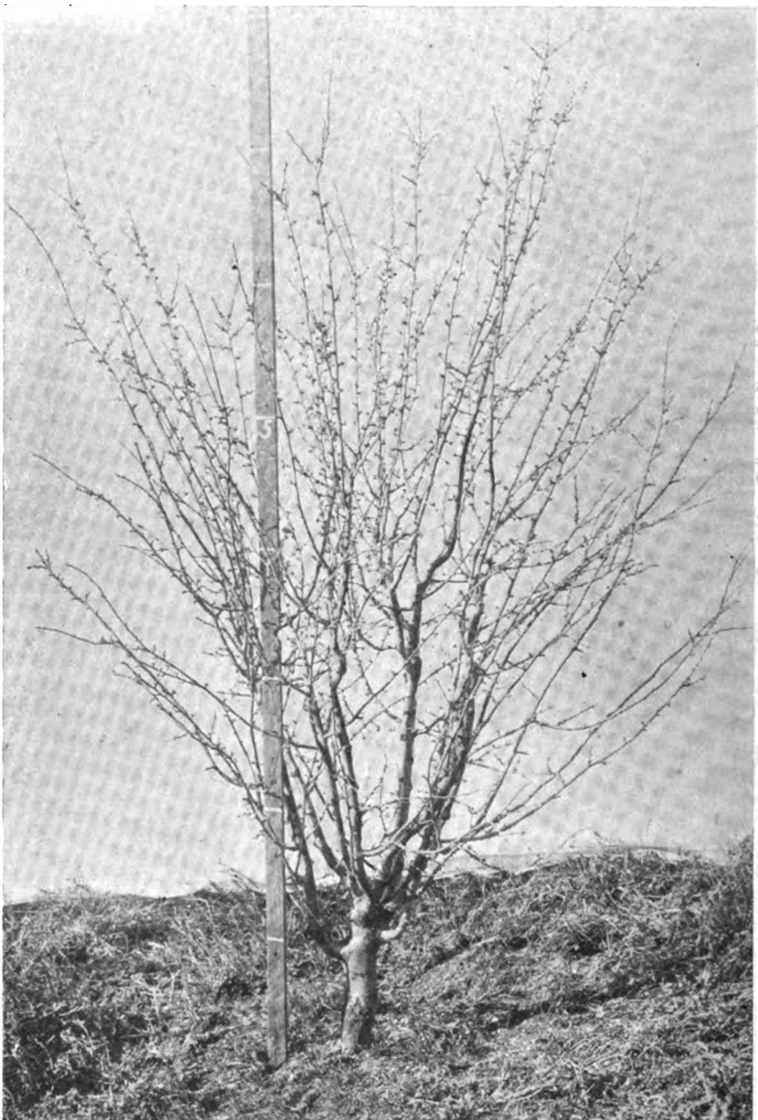

PLATE 8
PRUNE TREE

The plum roots made no more descent into the hardpan than did the peach, and suffered more from the heat of the surface of the soil. The illustrations of typical prunes are from among the best trees, except the Myrobalan. Many of the plums at twelve years of age were no larger than the seven-year-old Petite prune d'Agen, illustrated in Plate 8. The leaves of the plums fell from the twigs in early autumn; in years of greatest drought the trees lost half their foliage

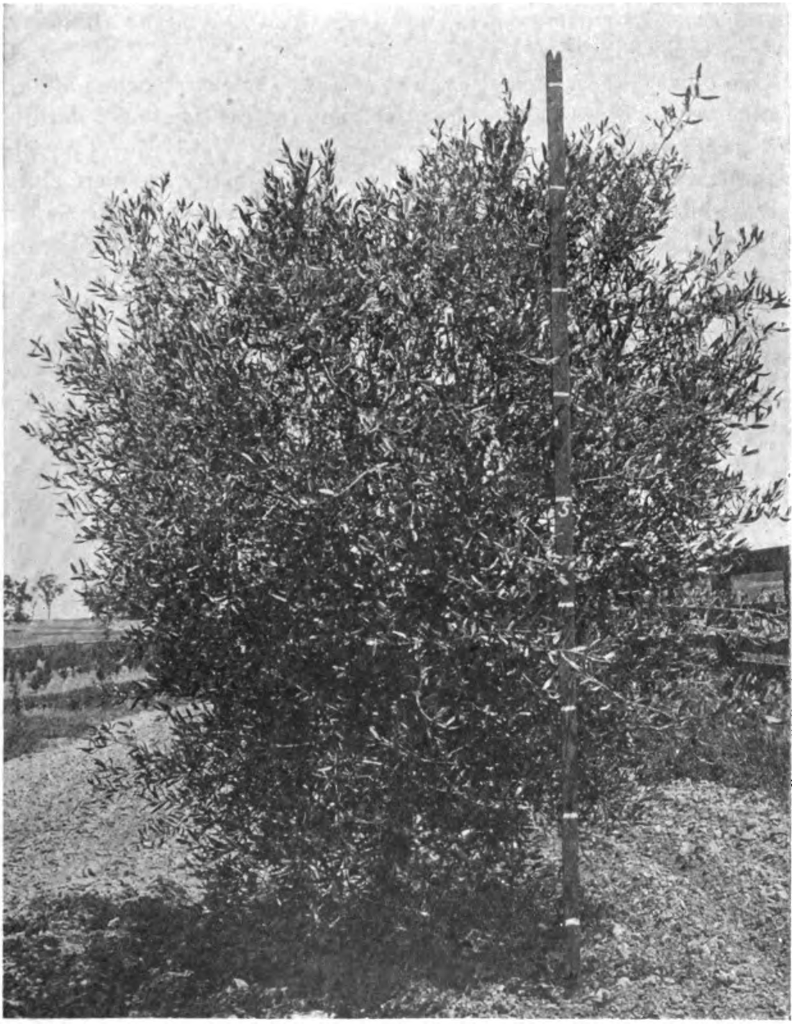

PLATE 9
OLIVE TREE

by midsummer, suffering in this respect more than the peaches, but not more than the apricots and cherries. Abnormal developments of numerous buds along the twigs especially marked the deterioration of the plums and prunes on hardpan soil.

Olives.—This period saw the definite abandonment of olives as a crop, new wood having been much injured by frost on all varieties for four successive seasons. The Redding Picholine bore small crops, and Oblonga, Corregiolo, and Præcox yielded a little. The trees almost ceased to grow, and the crop evidently had no commercial place in the locality.

One olive tree on the sub-station, Corregiolo, has reached a height of nine feet and a spread of five, but is not upon the worst hardpan. This tree was two years old when sent here in 1889. No other olive on the tract is more than one half as tall, and many are mere clumps of frost-bitten growth. Corregiolo, here illustrated (Plate 9), and Redding Picholine have been the hardiest. Plate 10 shows its root system on medium hardpan.

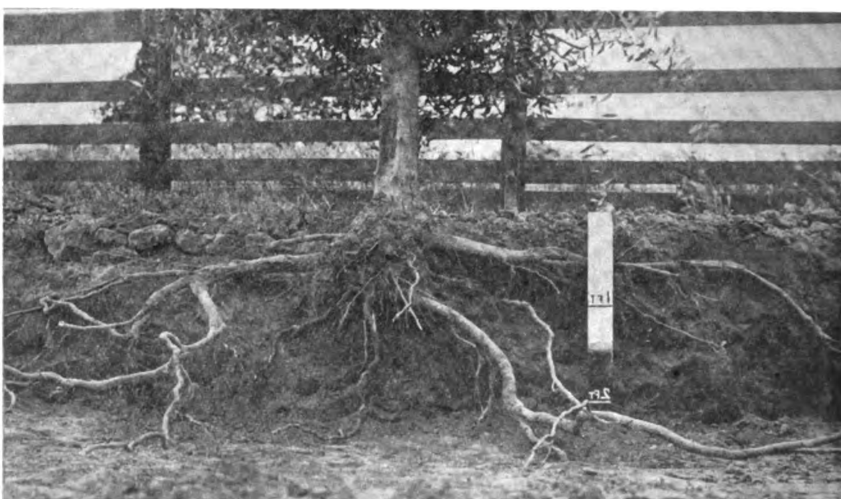

PLATE 10

OLIVE ROOTS ON HARDPAN

Grapes.—Three-fourths of the vineyard has been removed because of its ceasing to grow or to yield a crop on the hardpan soil. The roots of the grapes, while penetrating a little, in no case passed through the hardpan. The vines were consequently stunted, extremely susceptible to spring and early winter frosts, and a mass of knots, as shown in the photograph (Plate 11). The fruit was small and poor.

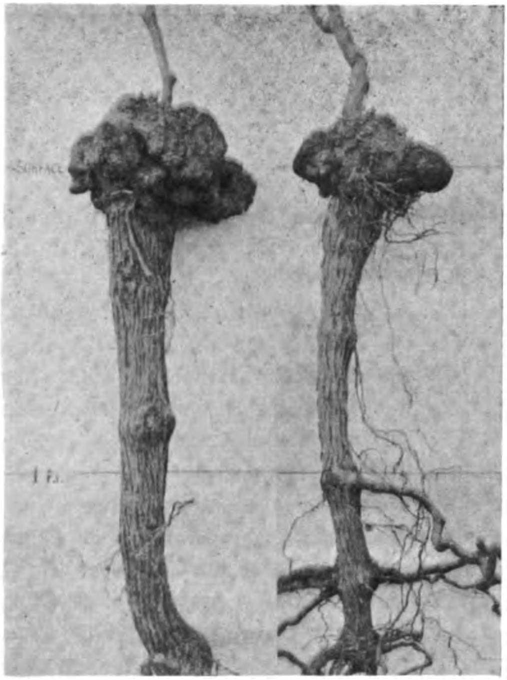

PLATE 11

GRAPE-VINE KNOTS ON HARDPAN

In no cases did a vine yield more than from five to ten pounds of fruit after 1896. On the more shallow soils, crops of two and three pounds to the vine were the average. Blasting and boring through the hardpan seemed to give some little aid to the grape-vine roots.

The vineyard, left after the removals of 1900 and 1901, contains nearly all the varieties originally planted and extends along the eastern side of the tract.

Other Fruits.—A few remaining figs that had escaped the late frosts bore a little. In 1897, Agen ripened fifteen pounds September 25th. A few others ripened some fruits before the early winter frosts came. In 1898 the trees were killed to the ground and removed.

Mulberries in these years usually lost the first crop of leaves, but the Persian did not. They continued to thrive on very poor and shallow soil. Alba, Lhoo, and Nagasaki bore large crops, and are valuable for poultry or swine. The Persian bore well, and is a valuable crop for domestic uses. Mulberries ripen here ten days later than at Shasta, which is 350 miles further north.

Chestnuts, English Walnuts and Japanese Persimmons succumbed. A California black walnut slowly penetrated the hardpan, held its own and continued healthy.

Conclusions.

During this period of six years, to the close of 1900, it was clearly shown, entirely aside from any soil question, that the climate forbids the successful culture of most deciduous fruits at the sub-station. Pears, apples, certain plums, a few peaches, and mulberries were all that gave continued promise of success here.

Aside from problems of climate, the granitic soil, on hardpan or otherwise, was soon exhausted and needed more moisture than the average rainfall to keep the trees in health. The hardpan soil was unfit for fruit culture. In order to remedy the difficulty as far as possible, holes were bored through the hardpan beneath selected trees. Close to other chosen trees, holes were blasted. The extreme thickness of the hardpan militated against success in these efforts, and of fifty trees of all sorts of deciduous trees thus treated, none, when removed several years later, showed growth down these channels. The soil was heavily fertilized on a portion of the orchard; another portion was sown to European lupins for plowing under, but the plants grew only three or four inches high. The only plant which throve in this orchard on hardpan soil and penetrated the hardpan was Atriplex semibaccata (Australian salt-bush).

The total number of trees planted between 1889 and 1897 on the hardpan part of the orchard, south of the swale, including all re-plantings, had been 455, on about two and a half acres of ground. It became necessary to remove for failure, because of soil or climate or both, 360 of these trees by December, 1898, leaving less than a hundred scattered specimens for further study.

Typical Reports by Varieties.

The following brief tabular reports show the behavior of different varieties of deciduous fruits in 1899 and 1900 and still further emphasize the poor condition of the orchard on the hardpan soil.

ALMONDS ON HARDPAN.

Variety.	Year.	First flower.	First leaf.	Crop ripe.	Am't. in lbs.
King's Softshell	1899	Feb. 19	Feb. 24	....	none
" "	1900	Feb. 3	Feb. 15	Aug. 4	4
I.X.L.	1899	Feb. 13	Feb. 22	....	none
"	1900	Jan. 26	Feb. 3	Aug. 4	7
Prolific	1899	no bloom	Feb. 27	....	none
"	1900	Mar. 2	Feb. 26	....	none
Pistache	1899	Feb. 21	Mar. 3	Aug. 31	a few nuts
"	1900	Feb. 12	Feb. 28	....	none
Texas Prolific	1899	Feb. 27	Feb. 21	....	none
" "	1900	Feb. 20	Feb. 23	....	none
Bidwell's Mammoth	1899	Feb. 17	Feb. 20	....	none
" "	1900	Jan. 26	Feb. 5	....	a few nuts
Marie Duprey	1899	Feb. 13	Feb. 28	....	none
" "	1900	Jan. 24	Feb. 18	....	a few nuts
Golden State	1899	no bloom	Feb. 21	....	none
" "	1900	Feb. 24	Feb. 19	....	none
Languedoc	1899	Feb. 24	Feb. 24	....	none
"	1900	Feb. 13	Feb. 25	....	none
Drake's Seedling	1899	Feb. 24	Feb. 21	....	none
" "	1900	Feb. 12	Feb. 20	....	none

Crop of 1899 destroyed by frost of April 23, 1899.
Crop of 1900 destroyed by frost of April 9 and 10, 1900.

So small an almond crop was practically of no value, and only showed that a few late flowers escaped frost.

The following sixteen varieties of apricot blossomed in 1899 and 1900, between March 1st and April 20th: Luizet, Newcastle, Peach, Turkey, Moorpark, Smith's Triumph, Orange, Alberge de Montgamet, Pringle, Purple, Large Early Montgamet, Royal, Blenheim, Routier, Beauge, Kaisha. The fruit of all was destroyed by frost.

The plums blossomed variously from March 1st to April 21st. Out of thirty-seven varieties remaining on the hardpan soil in 1899, only Blue Damson, Coe's Golden Drop, Oullin's Golden, Imperial Gage, Columbia, and Kelsey bore a few plums. All were stunted, diseased and dying trees.

The remaining apples on the hardpan held out longer than some other fruits, as the following table shows:

APPLES ON HARDPAN.

Variety.	Year.	First flower.	First leaf.	Crop ripe.	Am't. in lbs.
Keswick Codlin	1899	Mar. 30	Apr. 4	Aug. 15	48
" "	1900	Mar. 28	Mar. 20	....	none
Eng. Gold. Russet	1899	Mar. 25	Mar. 12	Sept. 12	24
" " "	1900	Mar. 24	Mar. 10	....	none
Missouri Pippin	1899	Mar. 30	Apr. 3	....	a few apples
" "	1900	no bloom	Mar. 20	....	none
Fall Pippin	1899	Mar. 25	Mar. 30	Aug. 23	39
" "	1900	Mar. 24	Mar. 12	....	none
Ben Davis	1899	Mar. 25	Mar. 30	....	a few apples
" "	1900	Mar. 20	Mar. 21	....	none

Peaches on Hard-pan.

None of 69 varieties of peaches that remained in 1899 and 1900 bore at all, since the April frosts destroyed the crops in both seasons. One nectarine, Victoria, escaped these late frosts and bore fifty-eight pounds of fruit. The bloom period of the peaches and nectarines was from February 20th to the middle of March, varying according to variety.

A New Orchard Planted.

In 1894 the old orchard of pears, apples, and other hardy fruits was extended north from the swale on the west side. In 1897 a large extension was made, consisting of apple and pear trees which had been grafted on the best obtainable stock to all the promising new varieties of which scions could be procured. These came from Europe, Canada, British Columbia, Australia, and many other places. Some were seedlings of note collected in Oregon and California.

Object of this orchard.—The three-acre new orchard thus established in 1897 was expected to show three things: (1) that upon this deep soil, free from hardpan, a healthy bearing orchard could be maintained with proper cultivation even in this region of fluctuating rainfall; (2) that the quality of the apples in particular was higher than on trees on the lighter soils; (3) that by careful selection of hardy fruits, much greater certainty of crops could be secured. After four years' experience with this orchard, all these results appear in a fair course of attainment. The trees are healthy; the few that have borne had fruit of excellent quality, and the Canadian, Swedish, Russian, and Scottish apples, as well as nearly all the pears, promise hardiness.

In addition to apples and pears, the young orchard contains many hardy cherries and plums, but these do not thrive as well as the pome fruits, owing to the extreme summer heats. Quinces and medlars have done very well indeed.

Views in the young orchard. One illustration (Plate 12) presented shows a Beurré Golden de Bilbao pear, one of several rows of like character on the dark adobe soil of the northeast corner of the tract. This would be thought a good tree in almost any orchard. It was one year old in nursery when removed, and had been four years in the orchard when photographed; head low, pruning severe, cultivation first class.

Another photograph (Plate 13, page 26) shows a view in the young apple orchard of the same age and treatment as the pears above noted, and other photographs show the largest apple and pear trees (Plate 14, page 27) left on the swale soil from the original orchard planted in 1889. But the black adobe is a better soil for these fruits than is the swale.

PLATE 12

PEAR TREE ON ADOBE SOIL

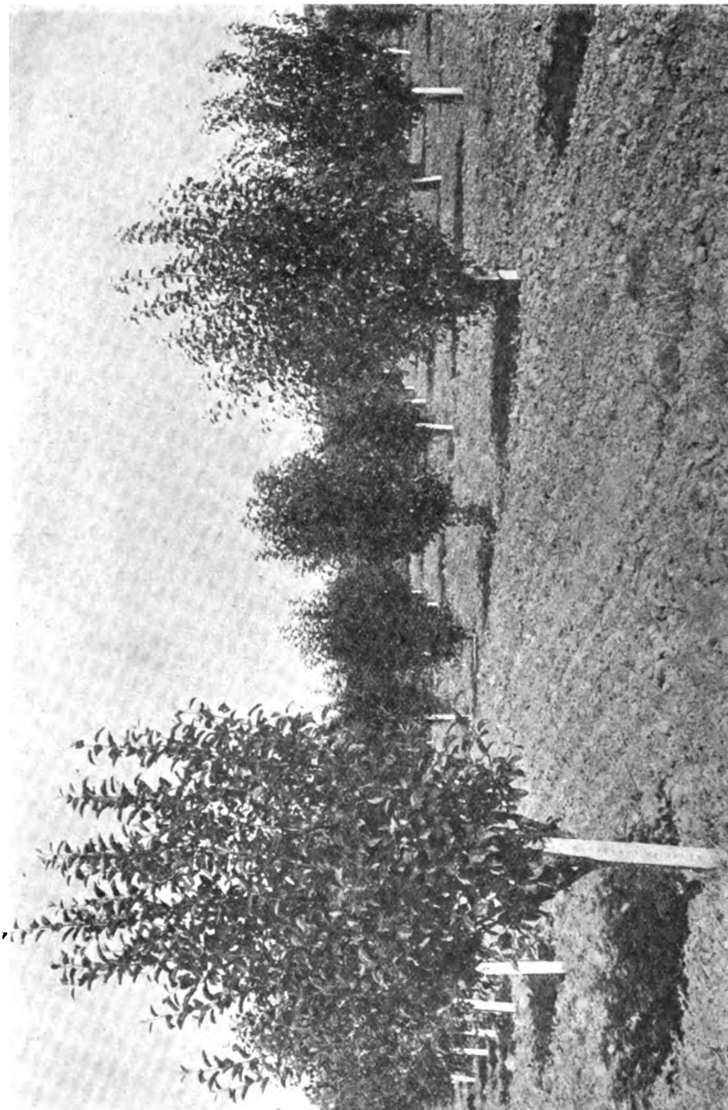

PLATE 13 (See page 24)
YOUNG APPLE ORCHARD ON SWALE SOIL.

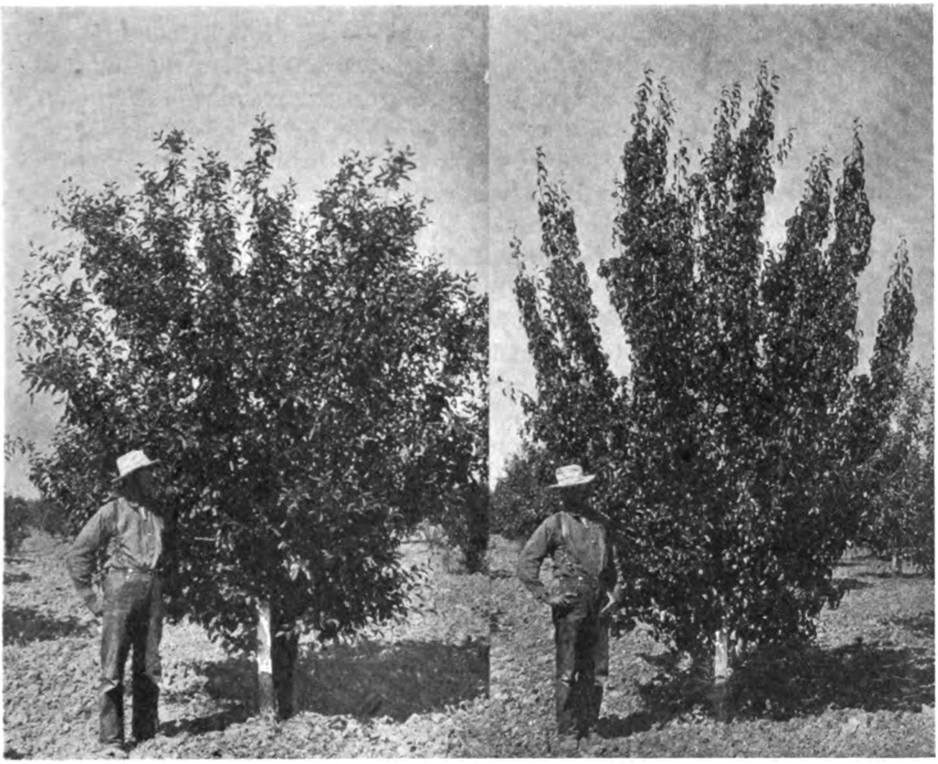

PLATE 14 (See page 24)

APPLE TREE PEAR TREE

Visits to Other Orchards.

The failure of so many deciduous fruits on the hardpan soil of the southern end of the station tract may be said to determine the entire unfitness of such soil for tree culture. Previous blasting and boring where such granitic hardpan is so thick will not avail, because in the course of time the hardpan is re-formed. The soil is entirely unsuitable for the growth of fruit trees, although, as the station experience has amply shown, oaks, mulberries, cork-bark elms, and a few other trees can establish themselves here.

But there are localities in this entire region, even east of the Salinas, where no hardpan exists, or where it is comparatively shallow and more easily penetrated, in which places orchards have done better. Some of these locations are less frosty than the sub-station tract, which makes a great difference in the growth of trees and yield of crops.

The foreman, Mr. J. H. Barber, spent a good deal of time in 1900 visiting and reporting upon orchards. At various times, when at the sub-station, I also went to see these orchards and examined the conditions which had favored or hindered them. The result of these investigations over a wide area was to confirm in the main the experience of the sub-station in respect to deciduous fruits. It is to be noted that the effort was made to hunt up those persons who were reputed to have *good* orchards and vineyards. No attempt was made to observe the utter and generally recognized failures, of which many exist. The notes which follow may, therefore, be understood as representing a fair and full statement of the best that can be said for deciduous fruit culture in this region east of the Salinas, upon soils sometimes better than the hardpan but no better than the adobe of the sub-station, and sometimes, but not always, in less frosty locations.

The Kilshaw orchard.—This place is three miles east of the sub-station, on a low hill among rolling hills, an excellent situation. The granite soil has some hardpan. Here were planted in 1893 250 almonds, Ne Plus Ultra, I.X.L. and Nonpareil, all on peach; and 250 French prunes on Myrobalan; earlier in 1890 a mixed orchard of nearly 500 apricots. peaches, plums, pears, apples, olives, etc., was planted. The trees have made poor growth, but in 1900 appeared healthy, except some of the older trees, which were reaching the hardpan or exhausting the soil. All the above trees bore well for the size of the trees and the lightness of the soil; frosts are not severe here. The almonds were the only profitable crop. These trees were well planted, 20 feet apart, well cultivated, pruned and cared for.

The Farington Orchard.—This orchard is near to Mr. Kilshaw's. One acre was planted in 1890, seven acres in 1891 and seven acres in 1892. All kinds of deciduous fruits are represented. The soil is a light, sandy loam for the peaches, a good, strong adobe for the others; no hardpan anywhere. Cultivation has been fairly good.

Plums died; prunes do well on adobe; nectarines crack open· pears are excellent—700 Bartletts now bearing; apples do quite well; almonds are not frosted. But the orchard does not pay, the pears coming nearest to a profit. The birds destroy much fruit, and the trees sunburn. A large part of the orchard has been taken out.

Iver Iverson's Orchard.—This quite noted place is on the Estrella plains. One thousand French prunes were planted, also 200 apples, in 1892. The mixed orchard then planted has been taken out. The soil is a strong adobe, with a chalky gray sub-soil.

Mr. Iverson's prunes have never paid, as the fruit is too small, and the hot weather sometimes "cooks them on the trees." The stock is Myrobalan, but Mr. Iverson's observations lead him to prefer almond, which he thinks stands drought better. Irrigation from deep wells, with engine, costs too much for this kind of an orchard. He expects to take the prunes out unless a very wet season gives them a start. The apples are fine, healthy trees, and large for the district. Astrachan, White Winter Pearmain and Yellow Newtown Pippin bore well in 1899 and 1900. "Quality was fair, but not equal to that of the coast apples" (that is, apples grown farther west, in the Santa Lucias, on San Simeon Creek, etc. A few trees of the Kelsey Plum (Japanese) bore very well. One fig tree is in bearing. None of the above fruits paid expenses, even for the local market.

Mr. Iverson planted 2000 grapes on this soil and found them profitable. He makes wine and sells table grapes. The Zinfandel shows black-knot; other varieties are free from it. Cultivation of both orchard and vineyard is with a weed-cutter; no plowing is done.

The Gordanier Orchard.—The well-known old orchard of Mr. Irving Gordanier is beautifully situated on the south bank of the Estrella River, between San Miguel and the town of Estrella. The soil is a sandy and gravelly loam, with no hardpan.

Twenty-five acres were planted to deciduous fruits in 1885; ten or twelve acres have been grubbed out, and more will follow. The leading fruits remaining are apricots (Royal and Moorpark), peaches (the leading commercial varieties), apples (Astrachan, Bellflower, etc.), pears (Bartlett, Winter Nelis, etc.), and prunes, French. The plums and cherries were an entire failure. This orchard was headed high and the trunks suffered heavily from sunburn, the cause of the loss of the cherries and plums. Frost often destroys the crop; since 1895 only one good crop (excepting of pears) has been obtained. When the trees were young the crop was of good size, but is now small, due to the lightness of the soil and lack of moisture. Cultivation has been fair, all weeds being kept down and the trees being pruned, but nothing more.

There has been "no profit on this orchard in any year." No fruit has paid for the labor and interest on the cost of the land, because of "frost, drought, and sunburn."

Jed. Mills's Orchard.—This is situated near the Gordanier orchard, on sandy upland. Fifteen acres of deciduous orchard here "did not pay," and thirteen acres were grubbed out. Late peaches do not mature by reason of the lack of moisture; early peaches do better; prunes failed. Pears have died from leaf-blight. In 1897, when the trees had been five years planted, there was a good crop of apricots, peaches, pears, and almonds, but almonds are generally frosted. Culture was fair.

This orchard has been only a source of expense. Trees failed as soon as they began to bear, and Mr. Mills thinks there is nothing in fruit for this region, excepting as a small family orchard to which sufficient water can be applied by irrigation. As there are few such localities, he practically discourages all orchard planting. His vineyard of one and a half acres, set in 1888, was frozen twice, but the vines recovered and now yield well. There is, however, no market against the shipments from outside grape districts, and "the only value of a vineyard is for home use."

The Proctor Orchard.—Mr. G. E. Proctor, two miles southeast of San Miguel, has twenty-five acres in fruit, chiefly prunes, but including all deciduous kinds and planted in 1892, 1893 and 1894. The prunes have been "about a quarter crop"; the almonds have suffered some from frost. The whole orchard has been injured by drought, and now it receives little care; it has proved unprofitable and fruit is too poor to ship to any market. Some hardpan occurs here. This orchard was planted in the very dry year of 1894, and is now failing.

Kirkpatrick Orchard.—This pioneer orchard is situated in Ranchito Cañon, east of San Miguel. Here Mr. R. R. Kirkpatrick in 1884 planted four acres of orchard and vineyard, and about twelve acres more in 1886, 1887, and 1892. The last plantation (of four acres) is all that remains. The soil is adobe with some gravel. Trees were set twenty-five feet apart. "In wet years crops were good". Frost has caused partial but not entire loss. Growth of trees was checked in every dry year, and therefore the orchard did not pay at all. At first the apples were very good, but as the tree aged, the fruit became small, dry and insipid. The same fact was noted with peaches, apricots, and nectarines. German prunes "were excellent for a few crops", then failed. English walnuts grew well only in wet years, but were often hurt by frost. A fig tree ten years old bore every year. Morello cherries at first grew very well; then suffered from drought and sunburn, died back and were grubbed out.

The culture of this orchard was excellent for some years. The fruit "never began to pay expenses." This orchard, like the two next described, is in the foothills east of San Miguel, but not on the Estrella Plain.

The Fowler Orchard.—Here fifteen acres were planted in 1884 and soon after, and ten acres have been grubbed out. History of the place is much like that of Kirkpatrick's. Nectarines did better than peaches;

"summer varieties of apples are good"; all the pears do well if deeply cultivated and headed very low; almonds were frosted or taken by birds. The chief drawback is lack of moisture, and the orchard "does not pay expenses."

The Faulkner Orchard.—Ten acres were planted in 1886 by Mrs. Faulkner in Ranchito Cañon, and were grubbed out in 1898 as unprofitable. Walnuts, chestnuts, and figs as well as apples, peaches, etc., were tried here. As soon as the trees were old enough to bear, they died back. The cause was drought and hardpan. The orchard received thorough cultivation. Two thousand rooted grape-vines and twenty thousand cuttings were planted here in March, 1888, but were killed by the northers and drought of that spring.

The Malmberg Orchard.—This is in the Linne settlement near the Huerhuero, where a number of hard-working farmers have homes. Mr. E. Malmberg planted about eight acres in 1895, and added some olives in 1897. The soil is a sandy loam with chalky sub-soil, on a slope. The growth so far is good; the trees are healthy and well cared for. The fruit is small (not well thinned). Olives and almonds so far are not injured by frosts. Trees show need of more moisture. Profit is very doubtful. Three acres are of muscat grapes; but the fruit was too small and dry for good raisins, so the vines were grubbed out.

Orchards of Geneseo Settlement.—This is a settlement of farmers, mostly Germans, about five miles north of Creston. They came here about 1885. There are no cöoperative features, but they have much social and religious unity. The Ernst Brothers and others came from Geneseo, Illinois—hence the name.

Between 1886 and 1890, these farmers planted a number of small orchards and vineyards. Everyone was then very hopeful of the future of this industry. Droughts, late frosts, and various discouragement have caused all or nearly all to lessen their orchards materially, but they have retained their vineyards, and a few have been enlarged. The records stands as follows: Wm. Ernst planted five acres of orchard and seven acres of grapes; took out three acres of orchard. John Ernst planted ten acres of orchard and nine acres of grapes; took out all his orchard. Martin Ernst planted six acres of orchard and ten acres of vines; took out four acres of orchard. Mr. Klaus (pastor of the little Lutheran congregation) planted, on the two acres of the church property, an orchard and vineyard which remain. G. Clingworth planted two acres of orchard and six acres of vines; added four acres of vines. Jacob Timkin planted ten acres of orchard and four acres of vines; took out seven acres of orchard. Charles Pepmiller planted seven acres of orchard and three acres of vines; took out four acres of orchard, J. Schlegel, M. Holziner, George Boneker and Fred Hirt planted in all thirty-three acres of orchard and vineyard, all of which still remain.

A more detailed account of several of the above orchards and vineyards was furnished by the settlers themselves. John Ernst, whose ten acres of prunes, small family orchard and ten acres of vines were planted in 1886 on the rich bottom land of the Huerhuero River, found in a few years that "the trees did not pay expenses." His vineyard of Mataro, Carignane, Burger, Rose of Peru, and other varieties, is profitable, as he makes wine for the local market.

David Paulus planted his orchard on light, sandy and gravelly loam, in 1889, the same year the station was established. He replanted where trees failed and regrafted many sorts. His apples and pears were on heavier soil and have done fairly well. The spring frosts have often destroyed the stone fruits. There is also "too little rainfall and the fruit is poor in quality as well as small." The orchard has always been unprofitable, though receiving excellent culture. The Burger grape is least subject to frost, but suffers from mildew.

Results at Geneseo Settlement.—Mr. William Ernst, who furnished much assistance in collecting and revising the data relating to this interesting group of orchards and vineyards, and who is thoroughly familiar with the history of them all, notes that, as at the sub-station, deciduous fruits of every kind grew well for a few years. The winters were more rainy and less frosty than some which followed, and the soil was new. The farmers felt much encouraged and thought they had a "first class fruit country." In 1890 four dollars profit was made from each early-bearing peach tree in some of these orchards. The cherries which bore in 1890 and 1891 also paid very well. Prizes were taken at county fairs for peaches, cherries, Japanese plums, pears, and grapes grown in the Geneseo district, and this was in competition with Arroyo Grande, one of the most famous valleys of San Luis Obispo county.

Then, as occurred at the sub-station, though the Geneseo settlers had a much better soil, usually free from hardpan, the trees commenced to fail in the dry years, could not recover, were grubbed out by the acre, and though a few orchards have been kept, in the hope for better times, the industry is practically abandoned and the remaining orchards are very poor. Mr. Klingworthy, whose location is less frosty, retains one of the best orchards here.

The local market has proved almost worthless, as "in good seasons everyone has fruit, and in poor ones there is none to sell." The long hauls to the railroads and high freights would prevent shipment of fresh fruit even if it were first rate in size and quality, which it can seldom be under these conditions. There has not been enough fruit to dry or can successfully for market, and the spasmodic crops forbid investment in the necessary "plants" for handling it. The farmers have come to depend upon grain and livestock with perhaps a small vineyard and a few fruit trees. No orchards are being planted by new-comers, and the few old orchards remaining are sadly neglected. The entire community feels assured of the unprofitableness of deciduous fruits here.

The feeling in regard to grapes is quite hopeful. Considerable wine is made for home use and local sale. It is in demand in Paso Robles and other towns where its use is said to be increasing. The grapes are high in sugar contents and the vines bear every year, and generally a good crop.

Orchards Near Creston.

Experience of J. V. Webster.—One of the most famous and best kept of the early orchards east of the Salinas was that of the Hon. J. V. Webster, who deeded the land for the sub-station and was for a number of years the Patron, or local trustee. Mr. Webster planted quite an orchard in 1887 on his home place near Creston. The soil is a decomposed granite. The orchard contained eight acres of apricots, and some peaches, apples, etc. Trees grew well until 1891; then the frosts cut back the apricots in spring and the trees died, a few at a time, until all were gone. The entire orchard during its whole life "bore not more than a bushel or two of fruit." Peaches were started too high, so they sunburned and died. Frost, heat and drought destroyed them, and in 1900 all remaining were grubbed out. The apples still yield some fruit.

Mr. Webster was formerly a very strong advocate of fruit culture in the upper Salinas, and more particularly in this region, but he now says, "A few trees are all one can afford to keep." His vineyard has been more valuable. Twelve acres planted in 1887—Mataro and Carignane with some table varieties—has always borne well and is profitable for wine. He prunes late, in February. He says, "All the decomposed granite hills about Creston will eventually be covered with fine vineyards, producing wine of first-rate quality."

The Angus Orchard.—Mr. E. Angus, east of Creston, planted in 1891 about eight acres of apricots, peaches, prunes, apples, and pears, and has now cut out about one-half. The fruit has been profitless. Grapes have been satisfactory. The soil is light, loose, and granitic.

The Blake Farm.—This place is situated in the foothills southeast from Creston, and twenty acres of almonds were planted here in 1889 —the largest almond orchard in the region. Since 1894 the orchard has been neglected. It has never paid a profit. The trees still live, though uncultivated for several years. Frost generally kills the crop.

The Ballard Farm.—The following statement made by Mr. E. B. Ballard, whose farm is three miles south of Creston, is especially worth printing just as it was written. The energy and ability of Mr. Ballard are well known in San Luis Obispo County, and if any one could make fruit culture a success here, he would be able to do so. He says: "In 1890 I planted a small family orchard of about 150 trees of the best varieties of apples, pears, prunes, plums, peaches, nectarines, quinces, cherries, and almonds. The said orchard has had good cultivation and fair pruning. The soil is adobe where the prunes, apples, and pears are planted; the other trees are on a more gravelly soil. Hardpan exists from two to three or in some cases four feet from the surface. Fruit crops during the past ten years have been failures, with perhaps the exception of the plums, prunes, and pears (Bartletts). Frost has generally been the greatest curse, but if the peaches did escape they could not be beaten in flavor. I have never tasted a cherry, apricot, quince, or almond grown on the place. I do not think an orchard in this locality profitable either as an investment or for family use, as fruit, when plentiful over the State, can be bought very cheap, and when a failure elsewhere it is safe backing that this locality has not escaped."

Some Orchards Near the Salinas.

The Shackelford Orchard.—This very notable orchard is one mile southeast of Paso Robles, east of the river, and here, in 1890, Mr. R. M. Shackelford planted thirty acres of Bartlett pears, 90 acres of French prunes, and 40 acres of Redding Picholine olives. The pears were on a light, sandy loam, 20 to 40 feet above the bed of the Salinas the prunes were on a higher bench, and the olives on the rolling uplands. The culture was excellent for a number of years, but the orchard "never paid expenses, or near it," and has, naturally, been neglected. Frost and drought were the causes of failure. The pears are said to have paid for themselves, and were the most promising crop.

The Van Elliott Orchard.—This is a small, well-kept orchard west of the Salinas, beside the river and within the town limits of Paso Robles. Ten acres, chiefly prunes, were planted in 1887 and 1890. The soil is a gravelly bench land; some is river bottom. Cultivation was careful and thorough for some time, but "spring frosts rendered the orchard unprofitable," and it has not been pruned in recent years. The trees are healthy, but small.

Many small family orchards have been planted in years past on this low bench land, ten or fifteen feet above the Salinas or on the low hills near it, but still west of the river. Few of these trees remain, and little fruit is produced. When it escapes frost it finds ready local sale. Mr. Van Elliott had a few apricots, apples, pears, peaches, but mostly prunes. Experience shows that pear trees promise better than anything else here; large, healthy pear trees are often seen in old and neglected orchards along the Salinas.

The Thomas Orchards.—These lie southeast of Templeton, at the Mount Pleasant Ranch and the Eureka Ranch, and have received excellent care. Mr. A. L. Thomas, who is a prominent farmer of the district, planted four acres of almonds in 1896 which bore well in 1901. He also has sixteen acres of prunes, pears, and other fruits. On the Eureka Ranch, where he owns twenty-five acres of prunes and has charge of forty more acres, there was originally 185 acres of prunes planted and sold with the lands to colonists. About 120 acres are still kept up. The soil is granitic, mostly rolling hill; the fruit is small but very sweet. In the swales between the hills the trees, of course, grow much larger, and often yield better. The crop is frequently destroyed by frost. "None of these prune orchards have been profitable here. The hills are too dry and the lowlands are too frosty."

The Granger Orchard, near Shandon.—Two miles south of Shandon, east of the Salinas, Mr. Granger began to plant an orchard in 1884, and continued until he had forty acres of deciduous fruits. As at the sub-station, the trees did well while young and in years of greater rainfall. But they soon began to fail and the orchard proved profitless, so that thirty-five acres were cut out. Soil is a sandy loam on a stiff yellow clay. Pears "are the only fruit that never failed."

The rainfall at this place since 1884, as kept by Mr. Granger, shows some striking features. In 1884–5 it was 6.48 inches, but the next year it was 23.60 inches and the following year it was below eight inches. In the seventeen years between 1884 and 1901 it twice fell below four inches (in 1893–4 and 1897–8); it rose only eight times above ten inches, and in fact but twice during the whole period was it more than 14 inches. This is evidently not a country for the successful growth of fruits without irrigation.

Another orchard near Shandon is that of Mr. Shedd. Here are two very large fig trees, 32 years old. The orchard of three or four acres was mostly planted before 1880 and was in bearing to some degree in 1884. Almonds and apricots are often destroyed by frosts. Apples and pears bear, and so do the figs—three crops a year. The orchard and vineyard have received a good deal of irrigation by means of wind-mills. They were formerly profitable, but have been neglected in recent years.

Other Orchards east of the Salinas.—Many orchards not previously noted were looked up in the course of these investigations. One of the numerous failures found unprofitable, neglected, and abandoned is illustrated on page 37 (plate 15). One often sees in the corner of some grain field a few straggling fruit trees and vines.

Some of the orchards not previously described were, however, of a better type. One of these is that of Mr. A. J. Pinkstone, of Keyes Cañon, north of the Estrella. This is especially interesting because he has succeeded quite well with almonds. The place is sheltered in the cañon, and there are thirteen acres in almonds, peaches, apricots, figs, and walnuts.

On the famous ranch of Santa Ysabel, there is a promising young orchard, planted on three benches of land just east of the Salinas in 1890. The soil is a sandy loam, the lowest bench is close to the river, and the upper, thirty feet above it, is of more stony soil. "Cherries are dead or dying, almonds, apricots, peaches, etc., suffer from spring frosts. "The pears do very well." This orchard, like its neighbors, has been unprofitable.

A Few Successful Orchards.

There are a few places in the districts which have been described where men of unusual energy have done fairly well with deciduous orchards. The history of these enterprises thus, in some degree, relieves the otherwise gloomy records.

The Reynolds Orchard.—This is small, not over three acres. It is situated a mile east of the sub-station on the Huerhuero, and was planted in 1885 and later. The soil is a deep, alluvial loam, and "it is only ten feet to water." Apples, pears, peaches, and some other fruits, were planted. "All have made good growth and are healthy, excepting the apricots, which die down and finally succumb." Peaches bore every other year until 1898. Apples, pears, and prunes bear every other year and sometimes a large crop. Cherries have failed entirely. Grapes do well. The late frosts are the only drawback to the orchard (apricots and cherries excepted). Mr. Reynolds is able to irrigate from the stream, with a pump, in dry seasons and this, of course, makes a great difference. But he does not think an orchard profitable, even in this favorable location.

The Corbaley Orchard.—The next example illustrates sheer grit under hard conditions. Mr. J. B. Corbaley, who lives on the south bank of the Estrella, about two miles southeast of San Miguel, had

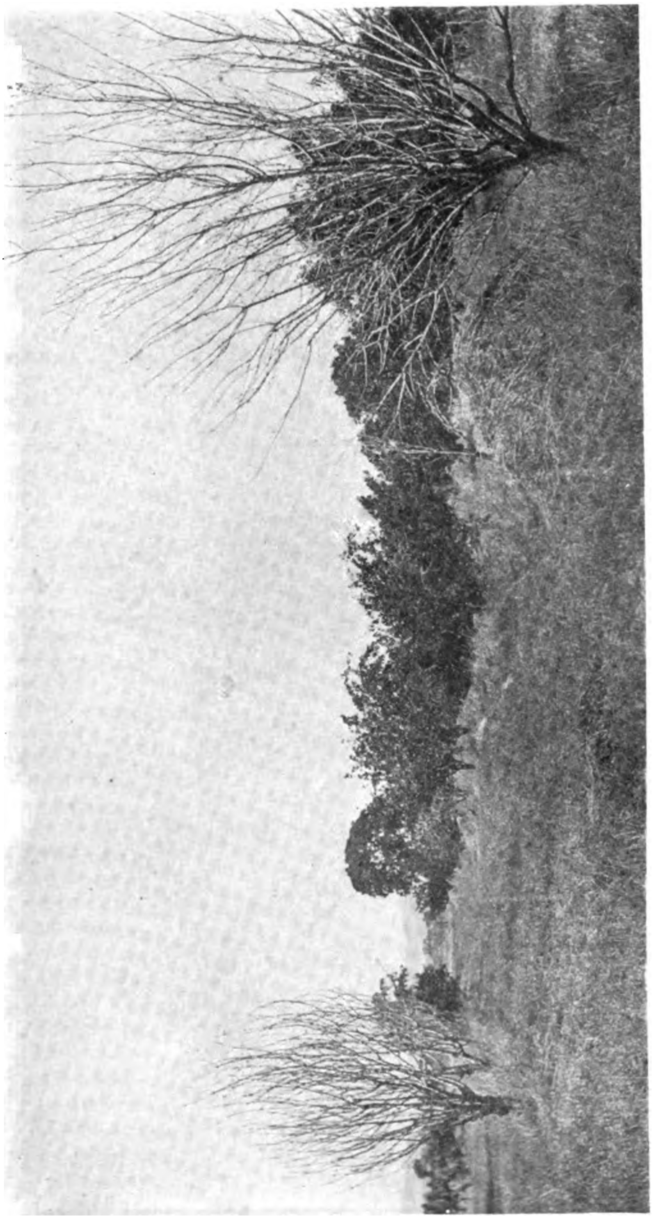

PLATE 15
NEGLECTED ORCHARD

twenty-five acres of deciduous fruits planted in 1890 and 1892, and took out five acres which did not pay. His soil is upland, granitic; no irrigation possible. Cherries died; apricots, almonds, and prunes fail in some years. Peaches, nectarines, apples, and pears have done well; "pears always bear." The prunes are poor, and he will substitute peaches, Mr. Corbaley "prunes heavily and thins heavily, plows and cultivates twelve times a year." He says that "fruit pays better than wheat." He grows melons and vegetables as well as fruit, and finds a local market. Peaches and pears are his most profitable fruits. "Late frosts are the greatest drawback."

The Webster Orchard.—The illustrations, pages 39–40, (plates 16 and 17) show the advantages offered by the so-called "Salinas bottom" on either east or west sides of the river, which are too frosty for many fruits. Mr. G. Webster, a well-known lawyer of Paso Robles and San Miguel, owns a farm half a mile from the latter town. Here he began to plant trees in 1893, and has continued until his orchards, in 1900, covered twenty five acres (pears, peaches, apricots, and prunes), and he planted in 1901 some 1700 Bartlett trees, making nearly thirty acres altogether of this pear, his best crop.

All his trees near the river bottom, a few feet above the sandy bed of the stream and on a light, rich loam, have grown well; trees on higher bench lands, twenty to forty feet above the former, have suffered from drought. The larger part of the orchard is about fifteen feet from the water. The culture consists of several plowings, and late spring cultivation. The orchard is well pruned. A part of the orchard has been in bearing since 1896. In 1900 everything "excepting pears" failed by reason of frost. Mr. Webster, on land just east of the river, "had only one failure of the pear crop in ten years."

Peaches sell in the local market, and are dried, but neither peaches nor prunes pay well. Apricots have not succeeded. Pears are "much the best crop here." The Bartlett pears grown by Mr. Webster, as well as all pears produced in the region, wherever the soil is suitable and the moisture sufficient, both east and west of the Salinas and north as well as south of San Miguel, are of unusual quality and beauty. Besides, the Bartletts are very late, and so find ready sale at the canneries in San José and elsewhere. Mr. Webster's pears are all sold by contract at a good price. He finds his pear orchard profitable, and is extending it rapidly.

The Steinbeck Orchard.—There is a noted orchard at Templeton (shown on first page) where 1600 Bartlett pears and a small collection of other fruits, were planted in 1890 on two benches, one low, just above the river, the other higher and on more gravelly soil, underlaid

PLATE 16

ORCHARD OF G. WEBSTER
(Mesa Plateau beyond)

PLATE 17

BARTLETT PEAR ORCHARD
(G. Webster's orchard)

by siliceous rock. The lower orchard is 15 feet to water; the upper is 25 to 30 feet.

The apples failed in 1900, but bore well other years; "summer varieties do best." The prunes "bore only once, in 1897." Peaches bear in some years. But pears are "the only profitable fruit, and that only on the lower bench," as in some seasons there is not enough moisture on the upland to mature a crop. In 1899 the crop was sold to San José canneries, delivered at the railroad station, for $42.50 per ton, sizes two and a half inches and upward. In 1900 the price obtained, delivered in San Francisco, was $25.00 per ton, sizes two and a quarter inches and upward.

In this orchard the Bartletts ripen earlier than at the sub-station and in some other orchards. In 1897, fruit was shipped before August 12th; in 1898 from August 18th to September 5th; in 1899 from August 21st to September 1st; in 1900 August 30th. Bartletts of large size and high quality are grown at the sub-station on the adobe soil, and, of course, without irrigation, ripening in mid-autumn. Picked September 29, 1897, they were fit for table use October 7th. The highest-priced Bartletts grown in this entire region will be such late fruit as this, produced on heavy soils in the hills, not always necessarily on the river bottoms. The experience, however, of Mr. Steinbeck, Mr. Webster, Mr. Reynolds, and others shows the road to commercial success on lands near the streams, whether the fruit be late or early.

The Nelson Orchard.—In order to show the conditions which prevail in the foothills east of the Salinas, though only a few miles distant, the orchard of Andrew Nelson, two miles northwest of Paso Robles was examined (page 42, plate 18). Here are twenty acres of mixed orchard, on a black loam underlaid by bituminous shale, and in places by limestone. Some of it is an ashy adobe. All is on rather steep slopes. The fruits growing here are almonds, nectarines, plums, prunes, apples, pears, figs, and oranges (which last were never injured by frost). Part of the trees were planted in 1890 and part in 1897. There has never been a failure of the fruit crop at this place; the trees grow well, though not large, and appear healthy. Mr. Nelson finds "fruit growing profitable for the local market," especially "when the late spring frosts destroy the crops in the valley and east of the river."

History of Fruit-Growing in this Region.

In the light of these notes, (1) from the sub-station between 1889 and 1902, (2) from the actual experience of those land-owners in the region who have made the most strenuous, and, on the whole, the most successful efforts to grow fruit, a brief account of the earlier history of the industry here tends to cast light upon its probable future. My authorities are the files of the early newspapers, my own observations, and the testimony of nurserymen and their agents, also the evidence of all the farmers interviewed.

Settling Eastern San Luis Obispo.—The story is one of a great and praiseworthy awakening of an entire community. Many of the investments then made were poor or worthless, but there was very little deliberate fraud. All men believed in this new, rich, beautiful region; those who have suffered most are still believers in the future of eastern San Luis Obispo and southeastern Monterey. Its story has been told with great force, skill, and truthfulness by Mr. Vachell, the novelist, in his "The Profession of Life," whose "Clumville" is Creston.

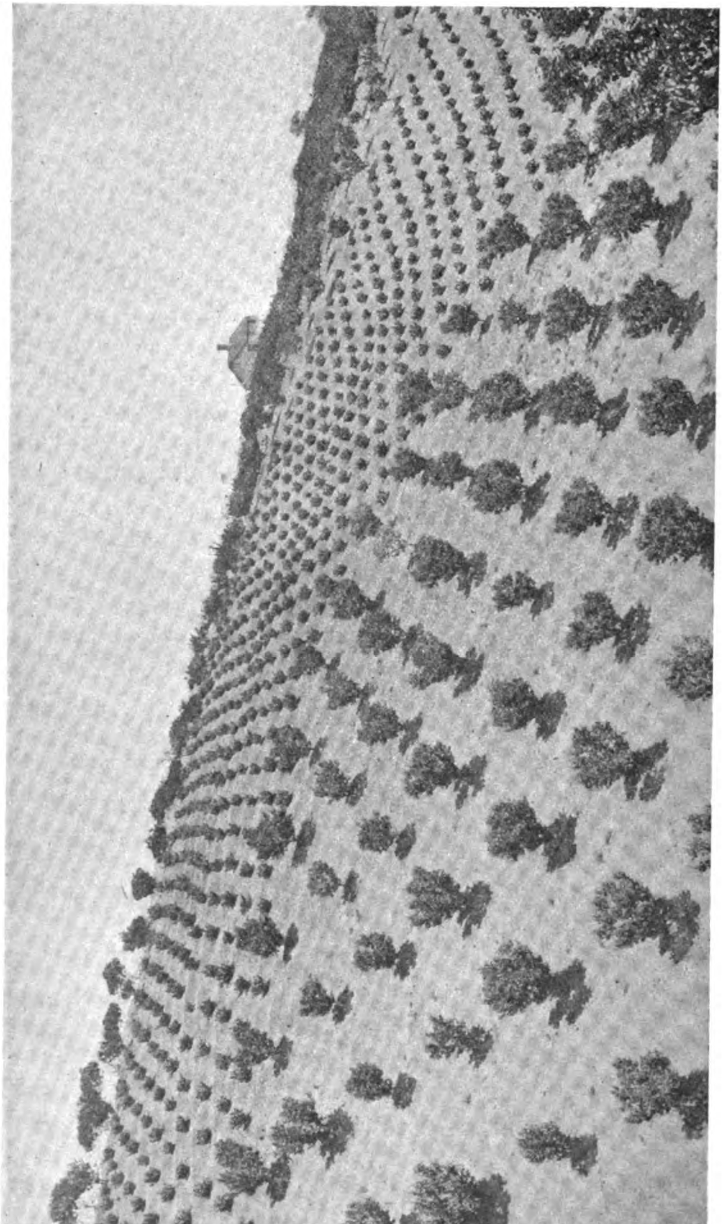

PLATE 18
ORDHARD OF ANDREW NELSON

Turning back to 1879, ten years before the sub-station was under way, a speculator of Napoleonic energy, C. H. Phillips, was breaking up the old Spanish ranches with every prospect of establishing upon them thousands of prosperous homes. His pamphlets said, "Paso Robles Rancho, 26,000 acres, adapted to wheat and grazing; Santa Ysabel Rancho, 23,000 acres, well watered, large amount of timber (oak); Eureka Rancho, 25,640 acres; Asuncion, Atascadero, and Santa Margarita ranches, in all 60,000 acres, and the Huerhuero Rancho of 43,000 acres." In addition to these were many smaller ranches east of the Salinas, and a great deal of government land. Incidentally, stress was laid upon the value of much of these lands for fruit growing, but cattle and the cereals were undoubtedly considered the main resource, and "wheat was king."

Views of the Pioneers respecting Climate.—The climate, broadly speaking, was very attractive to many persons, and the country was and is strikingly beautiful with its rolling hills and oak forests. Rainfall, as far as could be ascertained, though sometimes short, seemed as a rule sufficient for wheat. The few American pioneers gave about the following account: 1861, "very wet"; 1862, a "good grass year;" 1863, "very dry": 1864–68, "fair average rains"; 1870, "dry"; 1871–74, "good medium years"; 1875, "very wet"; 1876, "dry and cold"; 1877, "a wet year"; 1878, an average season; 1879, "wet and warm." With such reports it is no wonder that the literature of the period spoke of the upper Salinas as another Santa Clara of the north, and predicted that "cities like San José would spring up along its course and that of its tributaries." Accurate observations of its rainfall and temperature would in all probability show that the climate had not noticeably changed during a half century. Myron Angel's "History of San Luis Obispo County," published in 1883, says of San Miguel, "The lack of water is most pronounced and effectually debars the cultivation of most agricultural products save in exceptional years," and he mentions in 1878 a "cold spell" of 16° Fahr. As for the Estrella region, he speaks of droughts as occurring "two years in five," and, as this was from the standpoint of wheat culture, it would measurably agree with conditions during two decades since.

Early Faith in Orchards.—Some tree planting had been done in the Santa Lucia Mountains, in the Summit School district, as early as 1870 I sold trees myself to the pioneers there, and some are still bearing fruit. Tree planting in the valley followed fast upon the extension of the railroad, the laying out of Templeton, and the sale of lands east of the Salinas. In 1888 the Paso Robles *Leader* said, referring to the immense region east of the Santa Lucia Mountains, some 1,100,000 acres, "two-thirds of which was vacant, held for speculation or occupied for grazing", that "throughout this region, wherever tried, fruit of many varieties and of finest quality is grown."

Orchard Planting on a Large Scale and the Results.—Between 1885 and 1893 the planting of fruit trees on a commercial scale went on in all the farming regions tributary to the towns along the Salinas between San Ardo and Santa Margarita, fifty-three miles. Oranges, lemons, figs, olives, and other semi-tropic fruits were often planted, as well as all the deciduous fruits and small fruits known to the trade. Nurserymen sent out agents; places called "yards" for the sale of trees were opened in the towns. One then saw dozens of farmers coming in with wheat and going out with from 50 to 100 trees apiece.

Even in localities well adapted to fruits a large proportion of the trees sold by nurserymen never reached bearing age, by reason of neglect or ignorance. In new districts and those where, as it turns out, the difficulties in the way of success are very great, this percentage of loss was indefinitely increased. It is the opinion of those who sold trees during the "boom" years in these towns that more than one million trees of the leading deciduous fruits were sold and planted. Theoretically, this should have produced 10,000 acres of orchard; in practice it has produced only a few hundred acres, mostly west of the Salinas. East of the river, as these observations prove, there are only a few small and unprofitable orchards remaining out of all the planting done through so many years, and done in not a few cases by men of long practical experience in fruit growing in other parts of California. Settlers came here from Sonoma, Alameda, Santa Clara, Santa Cruz, Santa Barbara and other counties, as well as from the coast valleys of San Luis Obispo. They were therefore able to put average California methods into practice to some extent from the beginning, and if the region had been fairly well adapted to the culture of these fruits, they would doubtless have succeeded. Their almost total lack of success with nearly all kinds of fruits planted can be attributed only to soil and climate.

CONCLUSIONS.

The Sub-Station Records.—In the preceding pages are gathered up very briefly, if the mass of material collected be considered, the practical evidence on deciduous fruit culture in the region under consideration. The reader is further referred to the following articles in the Reports of this station: Report of 1887–8, published in 1889, pp. 13–16; Report of 1888–89, published in 1890, pp. 89–111, also in appendix, list of fruit trees planted at the Southern Coast Range sub-station; Report of 1890, published in 1891, pp. 278–287; Report of 1891–92, published in 1893, pp. 35–46, 150–152, and 193–202; Report of 1892–4, published in 1894, pp. 379–401, also in appendix, list of fruits planted at Southern Coast Range Station; Report for 1895–7, published in 1898, pp. 248–253, also 329–346; Report for 1897–8, p. 224, and pp. 278–292. This makes a total of 139 pages, besides the appendices, devoted to the records of the sub-station, and this consists chiefly of notes on soil, climate, orchard and vineyard history and other cultures. The conclusions drawn from this material, and from all other station records, too voluminous to be used in full, have gone to the writing of this bulletin.

Sub-Station Conclusions.—As regards the sub-station tract and land similarly situated in respect to water, to rainfall, to frosts, and to characters of soil, conclusions are as follows:

Given as conditions, a total annual rainfall sometimes as low as 4.75 or 5.58 inches, a small water supply wholly inadequate for irrigation, lifted from deep wells; killing frosts in the blossoming season and a light, granitic soil on hardpan, fruit trees cannot be successfully grown. Given a better soil free from hardpan, and especial care in culture, pruning and treatment, and pears succeed. Pear trees and hardy American plums will bear well in ordinary seasons, that is, in four years out of five, and by thorough cultivation can be carried through dry years without injury. On such soils, apples are likely to bear three years out of five, and peaches and nectarines will bear two years out of five. Persian mulberries will bear almost, or quite, every year. Grapes can be expected to yield fairly in four years out of five.

Neglect in culture or pruning, failure to destroy the borers or to start young trees very low, will end in the ruin of such an orchard, which is a highly artificial and most difficult product. On such land the pear would come nearest to actual profit. These discoveries of the value, in very arid and frosty locations, of these few fruits, and of the uselessness of planting on such hardpan, if properly heeded, should save land-owners much loss hereafter. So varied are the farms east of the river that on many farms a more suitable place for an orchard can be chosen, and the value of the farm thus increased.

General Conclusions about the District. Reviewing the entire history of the efforts to establish orchards east of the Salinas, it is clearly evident that the most severe losses have everywhere occurred in *almonds. cherries, prunes and apricots.* It is useless to plant these anywhere, excepting in a few sheltered spots, on good, well-watered soil; and, in fact, their culture belongs a considerable distance west of the river. Even four miles west of Santa Margarita (the Baron

Von Schröder ranch) 240 acres of prunes have been dug out, as the crop was invariably destroyed by frost. Measured by the standard of a commercially profitable tree elsewhere, not one first-class cherry, almond or apricot was found east of the Salinas River in 1900 or 1901, although the region was searched with great care. Thus measured, very few peaches or nectarines, plums or prunes have been found east of the river. Good apple trees were not numerous, but when on suitable soil they did fairly well, and there is sufficient evidence that peaches can be grown successfully in many locations and in ordinary seasons.

On rich soil, sufficiently moist, pears are the safest fruit crop for this entire district, as they withstand frosts well, and the quality of the pears is higher in this hot, dry climate than that of apples. For market, then, one must depend at present upon pears, and on lighter soils upon grapes. If peaches bear, and the trees are healthy, add peaches. For home use, plant grapes, pears, apples, peaches, nectarines, American and hardy plums and Persian mulberries. Among small fruits, if some irrigation can be practiced, plant strawberries and Loganberries, which do very well. For a few years and in some seasons Russian types of Morello cherries will bear quite well, but the trees will perish in a few years. Japanese plums blossom too early in the spring to be safe from frost; in sheltered locations they are valuable, but should be worked on peach roots. The very few cases where figs, olives, apricots and walnuts have borne fruit regularly east of the river, are due to local conditions that do not exist to any general extent.

The problem is really reduced to very simple terms. As a *tour de force*, the sub-station has carried a young orchard on fairly good soil through a season of 4.7 inches of rainfall without loss or injury. But such a season would seriously hurt large, bearing trees. The early winter and late spring frosts can be largely avoided by choice of better local conditions and by selecting the hardier fruits. Poorer soils can profitably be fertilized for small orchards. But the difficulty of a fluctuating rainfall, sometimes insufficient for healthy tree growth, and this in a region of rolling hills, scantily watered and not at present capable of irrigation excepting on small areas of bottom lands, constitutes the fundamental problem. The most hardy fruits may be selected, planted on the strongest soil, headed low, cultivated and cared for with extreme skill, patience and labor; still, if the land lacks moisture sufficient to maintain these trees in health during dry years, what avails it all?

This question has faced the student at every turn for thirteen years, in every orchard east of the Salinas, whether of ten trees or ten acres, across the Estrella plains, along the Huerhuero, on the arid slopes east of San Miguel, Bradley and San Ardo, where hard-working American pioneers are doing their best to make a living and to improve their homesteads. These people will do all that American communities can to develop their region by depending upon arid-land crops, forage-grasses, salt-bushes, thorough summer-fallow for cereals, larger areas made pastoral, and the utmost using of irrigation where available. To them in the end, out of more exact knowledge, more capital, and concentration on a few things, greater prosperity will come.

Land-owners should root up stunted, unfruitful trees, which "cumber the ground." If they desire small orchards (so well worth having when successful) they should select location and varieties in accordance with the best experience herein given, and they should at first plant only a few trees, unless conditions for obtaining water are especially favorable. They should utilize, in dry seasons, even the smallest sources of water supply, and all their orchard practice should be of the most approved thoroughness. Fruit, barring exceptional cases and exceptional men, should be only a secondary resource of the land-owners in the region east of the Salinas.

But the advice of the station respecting fruits, summed up from observation and experience of many persons during a long period of years, is against large or costly experiments. Grapes can be grown at little expense, over a large area, to fill local needs for table and wine uses, but not for high-class raisins. A few fruits can often be grown quite well, with care, on a small scale, for family use; a still smaller list promises commercial returns in picked locations. The average farmer, busy with his grain-fields and pastures, is unlikely to give the proper care and outlay to such difficult work as this. Therefore, few more orchards will be planted until several wet and warm years such as have before occurred again rouse public interest. When this happens the prudent land-owner will "go slow," remembering past droughts and frosts.

Other resources of the Region.—Many prosperous districts in America depend agriculturally upon other things than fruit. The resources, visible or latent, of the territory described in this bulletin are ample enough to justify permanent investments. All of the "hardpan" soil will produce hardy Eucalypts and many other valuable forest trees, also salt-bushes, and other forage plants whose roots, like those of the native oaks, have the power of penetration. The cereals also grow on such soil with even small rainfall.

The location of the sub-station in part upon this physical hardpan, has resulted in the trial of a great number of plants here, and in much evidence respecting its value as well as its disadvantages. The winter's rainfall passes through it, and is in large degree stored up beneath. Plants whose roots can penetrate it to any useful extent are therefore invaluable here, and the list of such plants is being steadily increased.

The area of stronger soils, free from this peculiar hardpan, is large, and here the range of profitable crops becomes correspondingly greater. It has not been the province of this bulletin to discuss these broader possibilities of the region, but nothing herein written can justly be taken as implying their absence. On the contrary, such facts as those given respecting orchard limitations east of the river will, it is hoped, guide future investors to more profitable crops than fruit, and especially to a more general use of suitable forage plants and trees with penetrative roots upon neglected hardpan soils of this nature.

Many as yet but slightly developed fruit districts are scattered throughout the Santa Lucia Mountains immediately west of the territory under consideration in this bulletin, and from thence the dwellers on hardpan and the more arid soils east of the river will eventually draw much of their fruit-supply.

UNIVERSITY OF CALIFORNIA PUBLICATIONS.

COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

GRASSHOPPERS IN CALIFORNIA.

By C. W. WOODWORTH.

Young Grasshopper on Blade of Grass.
(Slightly enlarged).

BULLETIN No. 142.

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BENJAMIN IDE WHEELER, Ph.D., LL.D., *President of the University.*

EXPERIMENT STATION STAFF.

E. W. HILGARD, Ph.D., LL.D., *Director and Chemist.*

E. J. WICKSON, M.A., *Horticulturist, and Superintendent of Central Station Grounds.*

W. A. SETCHELL, Ph.D., *Botanist.*

R. H. LOUGHRIDGE, Ph.D., *Agricultural Geologist and Soil Physicist.* (*Soils and Alkali.*)

C. W. WOODWORTH, M.S., *Entomologist.*

*M. E. JAFFA, M.S., *Assistant Chemist.* (*Foods, Fertilizers.*)

G. W. SHAW, M.A., Ph.D., *Assistant Chemist.* (*Soils, Beet-Sugar.*)

GEORGE E. COLBY, M.S., *Assistant Chemist.* (*Fruits, Waters, Insecticides.*)

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*J. BURTT DAVY, *Assistant Botanist.*

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CONTENTS.

the Santa Clara Valley. It is quite possible that the insect has occurred and has done injury in other regions, and that orchardists have supposed the death of the affected trees to be produced by other causes.

Relatives of this Insect in California.—The California peach-tree borer belongs to the family Sesiidæ, a small family of slender-bodied moths, mostly day-flying in their habits, and often ornamented in a manner to suggest a wasp in color and shape. The species known as occurring in this State may be distinguished by the following synopsis:

SESIIDÆ.

Tongue long, (*a*); -rudimentary. Tibiæ tufted, *Paranthene*; -hairy, *Ægeria.* —(*a*) Posterior independent vein of hind wing arising from posterior vein, (*b*); -from center of cross vein, *Melittia;* -from end of cross vein. Palpi with long hairs, *Memythrus;* -short hairs, *Albuna.* —(*b*) Tibiæ hairy, *Vespamima;* -slightly tufted. ♂ abdominal tufts narrowing, ♀ abdomen with lateral tufts, *Sanninoidea;* - ♂ fanlike, ♀ none lateral, *Sesia.*

Melittia gloriosa feeds on sumac.

Memythrus robiniæ quite injurious to poplars and locusts.

Ægeria. Abdomen except base yellow, *pacifica;* -banded, *tibialis.* These insects attack poplars and willows.

Vespamima sequoiæ attacks pines and redwoods.

Sanninoidea opalescens on peach, cherry, apricot, and prune. The most injurious species of the group and the one treated of in this bulletin.

Albuna pyramidalis.

Sesia. Abdomen all blue, *achillæ;* -all black, *albicornis;* -sides, or all of last two segments red, *animosa;* -last three or four red, *behrensii;* -fourth and last two red, *polygoni;* -all banded white, *candescens;* -all banded yellow, *novaroensis;* -two white, *prosopis;* -two yellow, *neglecta;* - ♂ with two or three, ♀ with four yellow, *rutilans;* - ♂ with four, ♀ with three, *tipuliformis;* - ♂ with six, ♀ with five yellow. Fringe red, *rileyana;* -orange, *arizoniæ.*

The food of only a few of these species has been determined. The *albicornis* preys on willows; *tipuliformis* on currants and gooseberries; *rutilans* on strawberries; and *prosopis* in the galls on mesquit.

Paranthene palmii, the food of which is unknown.

LIFE HISTORY.

A good deal yet remains to be learned in regard to the life history of this insect. No one has thus far made very careful breeding experiments, nor has there been sufficient continuous observation of field conditions, to answer all the questions that might be raised in regard to it. The life history is known to be very different from that of the Eastern peach-tree borer, as occurring in the Northeastern States. It is possible, however, that the history of that insect in the southern limit of its range might be more like that of our species, but the knowledge which we have of it in the Southern States is quite as meagre as of this species in California.

Winter Condition.—This insect is best known in its winter quarters, because it is during the winter that practically all of the work for its repression is done. In striking contrast with the Eastern borer, our insect is more or less active all through the winter season, and the young worms grow and feed during all the warmer weather. It appears that pupation never occurs until well into the spring, even though the worm is quite large in the fall. This produces a tendency toward the production of a large spring brood of moths; but a great many of the worms that are on the tree in the winter do not transform until quite late in the summer.

The larvæ are found of all sizes during the winter. Farmers very commonly suppose that this difference in size represents distinct broods,

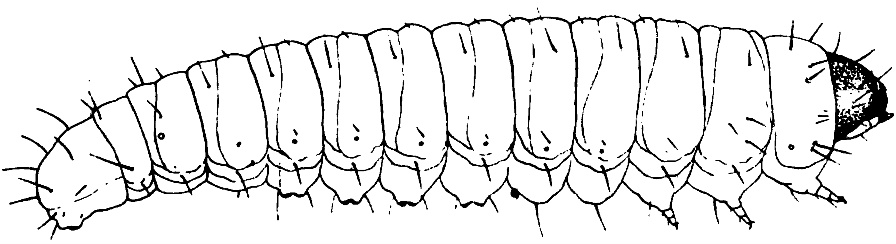


FIG. 1. A nearly full-grown larva of the Peach-tree Borer. Magnified four diameters.

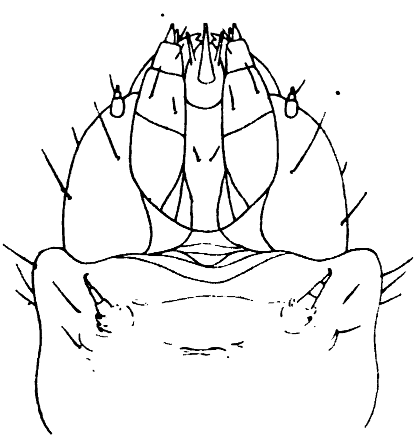


FIG. 2. The head from below. Still more enlarged.

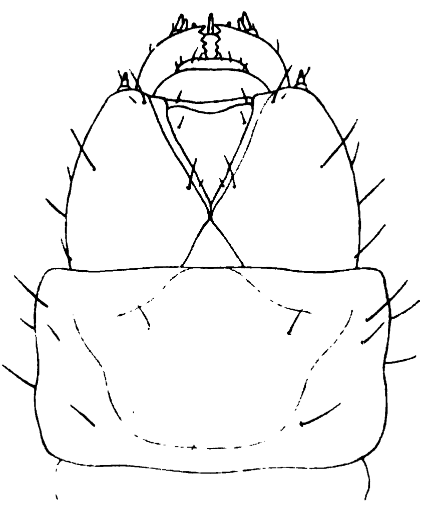


FIG. 3. The same from above.

and they commonly recognize three of these sizes, which they designate as the small, medium, and large sized worms. In fact, however, this classification is not sound, since every intergrade exists from the smallest to the largest. During the course of their development these insects molt like other larvæ, each stage possessing a very much larger head than the one immediately preceding it. The different stages can usually be quite clearly distinguished by the size of the head; but there is considerable variation in the size of two insects in the same stage, so that we have not been able to satisfy ourselves as to the exact number of molts. This will have to be determined by careful breeding experiments. It is not likely, however, that this information will have any very significant economic bearing upon the problem of suppression. There is a great deal of difference between the burrow produced by a young worm as contrasted with that of one of the older individuals, the former being always very shallow and usually quite devoid of gumming material, whereas the burrows of the large borers extend through the bark and into the solid wood, and are almost invariably indicated by the mass of gum on the outside. The time when the burrow becomes gummy, or when the insect penetrates deeply into the bark, seems to be wholly a matter of chance, or of individual peculiarity.

The Gum.—The most evident sign that the worm is working in the bark of the tree is the exudation of a greater or less mass of gum from the burrow. This gum mass is so uniformly present that most orchardists consider it an unfailing and only sign of the work of the insect. Our observations have shown that this is far from being the case. A great many larvæ were found by careful search, especially younger larvæ, in which there was no evidence whatever of gumming; and on the other hand, conspicuous masses of gum occurred very commonly where there was no evident sign of insect work.

It appears to be probable that the gum has no necessary relationship to the insect at all, but represents rather the evidence of the work of some decay-producing organism which has gained entrance to the tree at the point where it was injured by the feeding of the borer. Indeed, the presence of the gum seems to be distasteful to the borers, sometimes it even apparently causes them to abandon a burrow and start another. Gumming also occurs not uncommonly along the edges of wounds made from other causes, and almost always accompanies the attack of toadstool fungi where it occurs along the line separating the dead from the living bark. Gumming may occur where the insect attacks the tree above the ground, but is always more copious in the moist situations below the surface.

The fact that those attempting to cut out the insect depend almost wholly upon the presence of the gum for the discovery of the burrows of the larva, results in worms being overlooked in case the gumming has not yet occurred; or sometimes the tree may be very seriously mutilated in endeavoring to find a worm corresponding to a mass of gum which has been produced by other causes.

The Burrow.—Ordinarily, there seems to be a great deal of variation in the shape and direction of the burrow—about as many burrowing up as down. The general direction of the burrow is usually more nearly vertical than horizontal, though a few may go directly around the tree. Very careful study fails to reveal any decided preference as to the side of the tree affected, so it would seem that in all these matters the location or direction of the burrow is simply an accident.

Some have supposed that there is a certain definite arrangement that would have to be taken into consideration in the matter of treatment. The habits of the worms within the burrow are subject to no recognized rule. They appear to move about the burrow, according as the needs of feeding or cleaning-out compel them, with very little regard to temperature or time of day. The burrow appears to be always kept open by the worm, and the gum that gathers on the sides is pushed out with the excremental matter that accumulates in the burrow. Sometimes the gum hardens into a tube-like extension of the burrow, which may become as much as an inch long.

This gum tube is not to be confused with the silken tube almost devoid of gum, which is made by the insect as its transformation period approaches. The winter tube made by the Eastern species seems to resemble rather the transformation chamber than the gum tube. In many cases the transformation chamber contains more or less gum also, and indeed sometimes the tube is chiefly gum and excrement at one end, and silk and excrement at the other. Our species does not appear to have the habit of making winter tubes, but continues to feed through the cold season.

Spring Conditions.—With the commencement of the flow of the sap in the spring, the older larvæ proceed to the formation of their transformation tubes. These are sometimes, indeed quite commonly, formed within the burrows, especially if the amount of gum has not been excessive. In other cases they will be upon the surface of the bark at, or near, the mouth of the burrow. At no time of the year can a larger number of worms, preparing for transformation, be found than in the spring, due to the fact evidently that many of the wintering worms which had for a long while been full grown and were only deterred from transformation on account of the season, now suddenly find conditions favorable and proceed to prepare for their transformation. After the tube is formed and the insect ceases to feed, it still remains for some time in the larval condition, and if disturbed will wake up at once; indeed, it seems to be able to reproduce a new tube, if removed from the old one, without any particular loss to itself. Finally, however, activity ceases, the insect somewhat shrinks in size, and after a short period of complete rest, during which it is unable to walk if removed, the skin breaks and discloses the pupa which has been formed within. The life of the insect within the pupa does not last very long, exactly how long we can not state, and upon its conclusion the pupa becomes suddenly active, pushes itself out of the transformation tube and almost immediately gives forth the moth form. In Fig. 4, showing the pupa of this insect, will be seen the structures which aid them in this work of forcing the body out of the burrow. The sharp edge appearing on the head end of the pupa, seen best in the side view, enables the insect to break the structures ahead of it, and the spines which bound the back side of most of the abdominal segments hold the insect in place, or give it a point of leverage, so that it can, by bending its body back and forth, gradually force its way forward. After it has gotten into the open, the widely spreading spines, shown at the posterior end of the body, prevent further progress and hold the pupa case to the end of the burrow during the progress of the hatching of the moth. The line of splitting

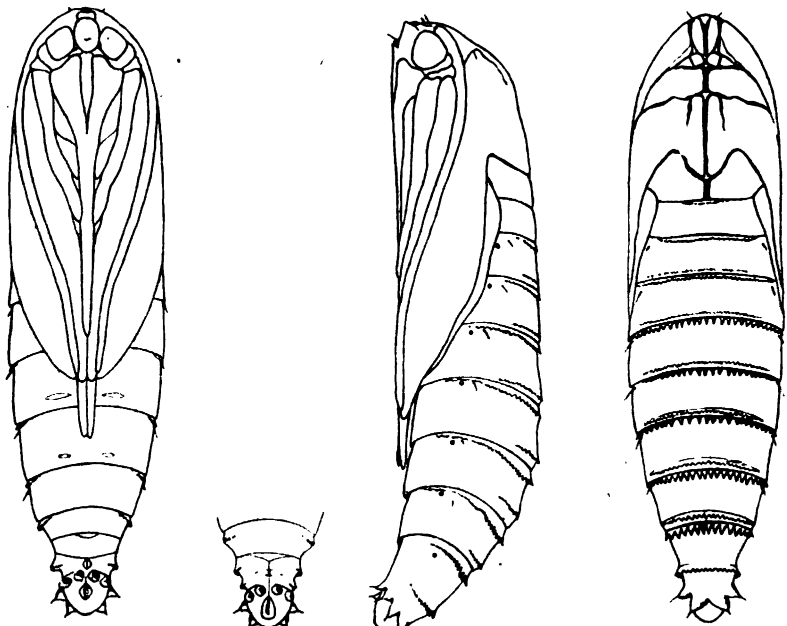


FIG. 4. Pupa of the Peach-tree Borer. Magnified about four times.

along the back, through which the moth emerges, can be seen in the right-hand figure.

The moth is not very commonly seen flying. Like the other members of the family, it flies in the daytime and not at night, as is the case with most moths. It produces a great many eggs, which are laid upon the trunks of the trees scattered about, apparently with no attempt at order. The egg is beautifully sculptured, slightly flattish, but oval in outline. The insect is quite prolific, laying some hundreds of eggs, and as they are, as a rule, laid singly, one moth can injure an immense number of trees. Young worms on hatching from these eggs enter some crack or crevice of the bark, where they lie concealed, eating into the substance of the bark, migrating about if the situation is not to their liking, and usually travel downward. As a rule, they are not satisfied until they get beneath the surface of the ground, where they find the bark still moist. If there should be a small amount of earth in the crotch of the tree they will very often select this place, and may come to full development in the bark there. After attaining some size, usually before reaching a quarter of an inch in length, the migratory habit seems to be almost wholly lost, and the insect will thereafter ordinarily complete its existence in one burrow. Throughout its life it is active, however, in keeping its burrow clean, sometimes going quite out on the surface of the bark in case the earth is loose, and if removed from the burrow will have no trouble in establishing a new one.

Summer Conditions.—Throughout the summer there is a continuous production of moths and laying of eggs, so that at any season of the year worms can be found of nearly every size. The spring brood of moths, however, which is, as already explained, unusually numerous, results in there being a size of worm fairly uniform and more abundant in numbers than those of any other size. These worms become full grown, or nearly full grown, by autumn, but do not transform until the following spring. Those individuals that are somewhat belated may not be half grown at the time of the dropping of the leaves, but they will generally be ready for pupation by the approach of spring. Sometimes the summer moths may in some regions become more abundant than usual, so as to produce a fairly distinct lot of worms of considerably smaller size than these spring larvæ. Occasionally, also, there may be a similar abundance in the fall. These peculiarities have given rise to the idea of three broods; but it appears that while there may be three times in the year in which the moth is more abundant than in others, and three fairly distinct sizes of larvæ, still each lot requires a full year for its complete transformation. The summer and fall broods do not by any means remain distinct from the spring brood, on account of the precociousness of some individuals and the belated development of others, the latter thus becoming a part of the preceding or succeeding brood. Commonly, the summer and fall broods can not be as clearly distinguished as the spring crop of moths.

The really significant part of the outline of the life history here given is that there is no time during the summer when eggs may not be laid, and that usually the largest growth of young worms occurs early in the season, but that occasionally equally abundant layings may occur at any time in the summer. It will not be possible under our conditions, therefore, to mark out any plan of annual treatment which will be equally effective in different years.

REMEDIES.

The remedy, upon which the most dependence is placed in fighting the Eastern peach-tree borer, is that of digging out the worms. The conclusion of the very elaborate investigation by the Cornell Experiment Station was that this process must form the essential part of any plan for the control of this insect. In addition to it, the use of *tar*, *tobacco stems*, *tarred paper*, or *mounding with earth*, must be resorted to. The first of these was found to be the most effective, but possibly dangerous to the tree under some conditions.

In California all of these methods and many others have been used quite extensively and with more or less satisfactory results, but they all certainly leave much to be desired, since they do not avoid the necessity of also digging-out. The digging-out process so mutilates the tree, even

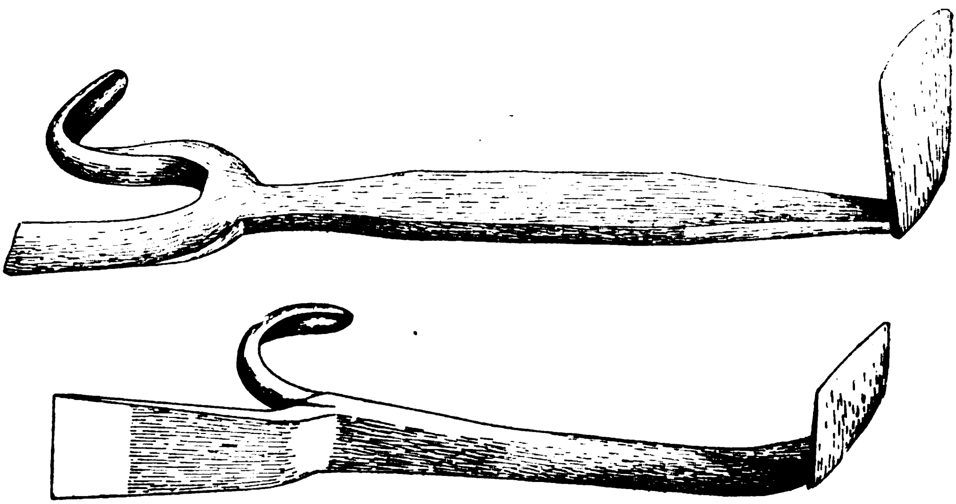


FIG. 5. Two forms of tools used in the "digging-out" method.

when the greatest care is exercised, that many growers are of the opinion that more injury is done than when the worms are left alone. When the digging is left to careless help, the tree is often very badly mutilated. Fortunately, the peach root heals over a wound very readily and is very tenacious of life, often keeping the top alive when there is but a narrow strip of bark left intact.

Digging-Out.—The tools used in digging-out are a shovel, and a pick if the ground is hard, together with a hoe or trowel for removing the earth, and a chisel, gouge, knife, or home-made tool for cutting out the insect. Several forms of these special tools are on the market in San José, two of which are here figured. Some growers prefer a blacksmith's hoof-knife instead of the form of gouge characteristic of these tools.

The time of the digging-out is almost always made a matter of convenience, and the facts we have so far learned in regard to the life history do not, as yet, prove that better results would follow a different practice. An important feature of the digging-out method is that it is extremely difficult to find all, or even the larger worms, in a tree; and if the worms are small their discovery is almost or quite impossible. A single going-over of the trees is thus only partially effective, and many orchardists have found that three times during the winter will not exhaust the supply, even though it is quite certain that no moths were flying during the intervals. The rush of other work usually prevents a summer digging-out of the worms, though it would seem that just as good or better results might follow from work at that season. We do not have sufficient data to decide accurately the relative value of the supplementary means used in connection with the digging-out process.

CARBON BISULFID.

A method that has given exceedingly satisfactory results under favorable conditions is the use of carbon bisulfid. The fact that under other conditions less thorough work was done, and that in some cases it has undoubtedly resulted in the death of the trees, does not signify that it is unavailable for the destruction of this pest. This substance has been used on a commercial scale only in California, though the suggestion was originally made for the Eastern borer by Prof. A. J. Cook, Conductor of Farmers' Institutes for southern California, then residing in Michigan. In Slingerland's experiments in New York it proved an entire failure, and was condemned by him as being too expensive, too dangerous to the tree, and entirely ineffectual against the insect. We have no record of the temperature or the condition of the soil in these experiments, and can only conjecture why the results were so unsatisfactory. Certainly, as used in the orchards about San José there is nothing as cheap as this method. When properly handled the danger to the tree is none; and in effectiveness, when conditions are right, it leaves nothing to be desired.

Danger to the Tree.—Carbon bisulfid has been used for so long a time as an insecticide for the control of phylloxera that we may be very confident as to its uniformity of action and efficiency against insects, and also of the extent of the danger to the plant.

As used against the borer the danger from this substance is wholly that of the action of the gas, since so little liquid is applied to each tree that it all evaporates before it would be possible for it to penetrate through the bark to the living tissue beneath. Some growers even make it their regular practice to pour the liquid on the bark, and without bad results. If enough material was used, or the soil was very wet so as to prevent evaporation, injury might come from the action of the liquid.

The effect of the gas is dependent upon its density and the length of time it is acting. Even the most delicate growing parts of the plant are tolerant of a weak dose of gas continued almost indefinitely. The point at which injury to root hairs occurs is very little beyond the point where it begins to be effective against insects.

With the more easily killed insects it might be possible to use the substance for the complete eradication of a subterranean insect, if we could obtain an even distribution of the gas in the soil.

In actual practice it is found that in the case of phylloxera the use of a strength that will be safe to the plant, almost always leaves somewhere a little colony of these creatures which are able in a short time to repopulate the vine and require another treatment. This repetition, every season or two, is very expensive in field work, so that it pays only in unusually valuable vineyards. The chief uses of this chemical have become, therefore: first, the stronger "death treatment," with which both vines and insects are destroyed together; and, second, for disinfecting cuttings or vines removed from the soil. In the latter case they are given a still stronger dose, but for a shorter period, and even though the smaller rootlets may be killed, the plant does not die, because being planted in new soil it can replace any dead parts at once. The bark-covered parts of the plant are many times more resistant to carbon bisulfid vapor than are the growing rootlets and root hairs, and these latter are quite as resistant as most insects.

In treating a peach tree, should there be any root hairs immediately about the crown they might be killed by the carbon bisulfid at the strength used, but this would not amount to anything to the tree. The danger to the tree would only come from a strength of gas and a length of time of treatment sufficient to injure the most resistant part of the root-system.

The amount used in any case should not be sufficient to cause the death even of root hairs very far away from the trunk; and the real danger to the tree is not from too great destruction of root hairs, but from the danger that the gas be retained about the crown in a concentrated condition long enough to cause the death of the more resistant parts of the tree.

The only thing that could cause this retention of the gas about the crown is the presence of water in the soil, which closes up the spaces between the soil particles, through which the gas gradually diffuses itself. The danger is greatest in heavy soils. In a very light, sandy or gravelly soil the difficulty would more likely be that the soil might be so dry that the gas would diffuse so rapidly as to fail to kill the insect; in that case, of course, being also perfectly harmless to every part of the tree. Practice has shown that there is a wide margin between effectiveness against the insect and danger to the bark of the tree. Intelligently applied, there is no reason why it might not always be entirely safe and effective.

Condition of the Soil.—The character and condition of the soil is the most important consideration in the use of carbon bisulfid. The same soil varies most greatly near the surface in the amount of moisture it contains, and unlike the phylloxera work, it is here in this variable surface soil that this treatment is to be made.

Extreme conditions should certainly be avoided, and uniform results require uniform conditions. The best results have usually been obtained in the orchards where the soil was rather light and in the best condition of tilth. Under these circumstances, the method of procedure is the simplest. All that is necessary is to pour the carbon bisulfid upon the ground around the tree close to the trunk and immediately mound up the earth a few inches against the base of the tree. In most soils it will be necessary, in order to secure the best results, to remove the soil that immediately surrounds the tree, as this is somewhat hard and packed, and to replace it with loose soil taken from the surface stirred by the culti-

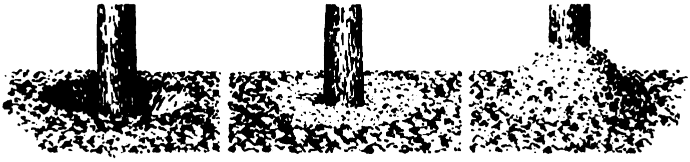


FIG. 6. Method of treatment in medium and heavy soils.

vator. This is made level and the carbon bisulfid applied as before, and more loose soil used in mounding. If the soil is rather wet or heavy it will be necessary to remove this soil impregnated with the chemical, so as to give the gas an opportunity to dissipate itself after a day or two, and thus prevent too long an exposure of the root crown to the gas.

Except on the lightest soils the earth should always be removed if a rain should intervene, as it will effectually seal up the gas and prevent its escape into the air.

In some orchards sufficiently dry soil may not be found for filling the excavations at the time it is desired to make the treatment, in which case chaff or straw may be used instead, covering it well with earth after pouring on the carbon bisulfid. This should, of course, also be removed after a day or two.

In very dry, light soils, if the carbon bisulfid dissipates itself too rapidly to accomplish the desired destruction of the borer, the use of water will make it effective. For this purpose, excavate around the trunk, then wet the soil, put back the earth, making all level, apply the carbon bisulfid, bank up the earth, and sprinkle the top slightly. In a day or two the extra earth may be removed, if it has not dried out enough to permit the escape of the gas.

The Dose.—In the matter of the quantity to be applied to a tree, there is a great deal of difference in the practice of different orchardists. Economy would favor as small a dose as will be sufficient, but if too small, nothing will be accomplished by the treatment, so orchardists generally feel that it is better to give too much than too little. It will not be possible to recommend a dose that will do for all conditions. Probably a larger number try to make their average dose about one ounce than any other amount; and this may be taken as a tentative dose to experiment with. Each orchardist must determine for himself that which will be best under his conditions. The most important factor in this matter is the degree of looseness of the soil. The heavy, compact, moist soils require the smallest dose; and the lighter, looser, and drier soils a larger quantity of the carbon bisulfid.

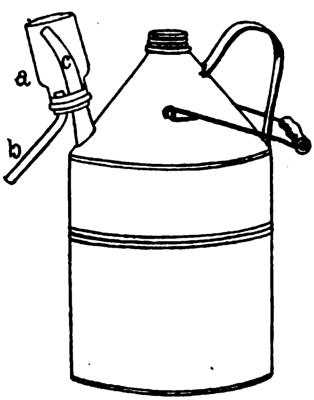


FIG. 7. Can for measuring dose of carbon bisulfid.

The common practice is to vary the dose according to the size of the tree, putting often several times as much around a large tree as a small one. Some little variation of this kind should occur, but not as much as is the practice. In an orchard with fairly uniform trees the best practice would be to make the dose uniform, without regard to the small variation in the size of the tree. A little change in the character of the soil in different parts of the orchard is a very much more significant matter.

The method of applying carbon bisulfid usually adopted is the use of a common machine oil-can. This has the advantage of convenience, but makes it difficult to apply a uniform dose. The deposition of sulfur in the spout decreases the rate of flow, and often gives trouble and makes the judging of the size of the amount discharged very difficult. We have planned a can by which a uniform dose can be rapidly measured and applied. It is shown in Fig. 6. It consists of an ordinary kerosene can, or a machine oiler could be used instead. A bottle (*a*) with a doubly perforated cork and discharge tube (*b*) is attached to the spout (*c*). The can is reversed until the bottle-measure is filled, when by righting it the liquid will pour out of the discharge tube. A bottle of any required size, fitted with perforated cork, can be had at any drug store.

Summer Treatment.—So far the use of the carbon bisulfid, like the digging-out process, has been almost wholly confined to the winter season. This has been chiefly because this season is the least busy, and partly because of the fear that there would be more danger to the tree if the chemical were applied when the tree was not dormant.

The danger to the tree at this season is not at all greater than when the tree is dormant, when the treatment is made in the manner employed for this insect. The drier average condition of the soil, which favors the rapid diffusion of the gas, may cause some trouble, on account of the difficulty of keeping the dose strong long enough to kill the insect.

Quite as much, or more, of the injury to the trees is done by the worms during the summer than during the winter, and it would seem desirable to make one or more applications to prevent this summer injury. As so many of the worms are small in summer, digging-out would be very difficult to do in a thorough manner; but carbon bisulfid finds no more difficulty in discovering a small worm than a large one, and the injury is stopped before it is hardly begun.

If but a single application is to be made, the best time to do it is early in the winter, after all the eggs have hatched and no more moths are flying. The earlier worms will have already done considerable injury by this time, which might be prevented by a midsummer treatment. Whether more treatments than these two will be profitable in most seasons it is not possible now to say, but careful observation of the condition of the trees in an orchard ought to enable any grower to come to satisfactory conclusions on this subject.

SUMMARY.

While the peach-tree borer is at present injurious only in the Santa Clara Valley, a watch should be kept for it elsewhere.

As far as known we have but one brood a year, but worms in all conditions can be found at almost any season, and moths fly and lay eggs all summer.

The presence of the gum can not be depended upon as an indication of the young worm, so that it is difficult to get all when digging them out.

Carbon bisulfid has proven a most efficient method of killing the worms.

The use of carbon bisulfid is not without danger to the tree, but with proper caution is safe.

The condition of the soil is the most important item to consider in the use of carbon bisulfid.

The soil next to the tree must be loose enough to allow the gas to reach every part of the crown, in order to kill all the worms.

Uniform treatment as to dose should be attended to. The time for the most important treatment is in the early winter. Probably, in addition, a midsummer treatment would be nearly as useful.

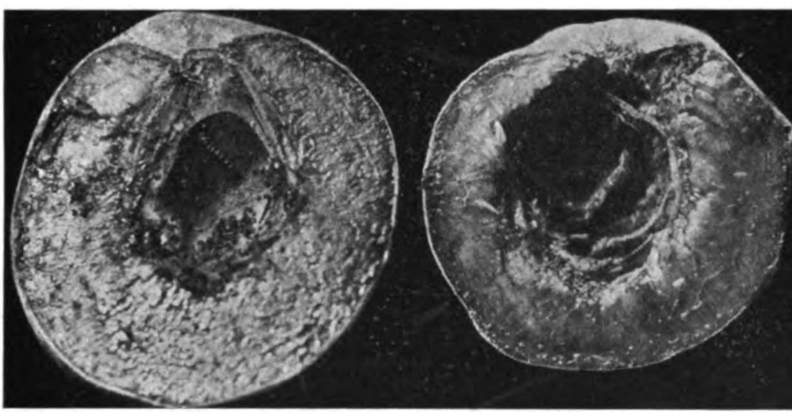
UNIVERSITY OF CALIFORNIA PUBLICATIONS.

COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

THE PEACH-WORM.

BY WARREN T. CLARKE.



THE PEACH-WORM AND ITS INJURY.

BULLETIN No. 144.

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CONTENTS.

THE PEACH-WORM.

BY WARREN T. CLARKE.

INTRODUCTORY NOTE.—The investigations reported in this bulletin were undertaken at the request and with the coöperation of the peach-growers of Placer County. At the Farmers' Institutes held last winter at Loomis and Newcastle this Department was urged to help in the fight against the peach-worm.

The work was finally made possible through the agreement, by certain public-spirited gentlemen at Newcastle, to provide for the local expenses of the study. These expenses were finally assumed by the Supervisors to the sum of $330. The University contributed the services of the Assistant Entomologist, W. T. Clarke, who began his work on the 2d of January of the present year, having his headquarters at Newcastle.

Early in February a press bulletin was issued, as a result of this study, recommending a method of treatment which has proven to be remarkably efficient. The majority of growers in Placer County, and doubtless many elsewhere, availed themselves of this information and have already reaped very material benefits.

The people of Placer County have left nothing undone that would aid Mr. Clarke in this study, and this bulletin represents the results of this year's spraying experience of practically the whole acreage of the largest fresh-fruit-shipping section of the State.

Many points in the life history of the peach-worm have been cleared up in this study, and the facts have been found to be in many important particulars at variance with the accounts of the insect heretofore published.

C. W. WOODWORTH.

Probably the most serious peach pest in California is the peach-worm (*Anarsia lineatella* Zell.), a widely distributed insect, attacking also plums and apricots, but so far as now known, confining its attack to the stone fruits. Its greatest and most evident damage is the injury to the fruit of the peach, grown for Eastern shipment as fresh fruit. In some seasons this loss has aggregated as high as thirty per cent of the entire crop. Some idea of the magnitude of the damage may be gained from the following table, which presents the losses suffered by the growers of fresh fruit alone during the past four years:

TABLE SHOWING LOSS DUE TO THE WORK OF THE PEACH-WORM IN FRESH FRUIT.

	Not Injured. Shipped.		Injured by Worm. Not Shipped.	
Year.	Carloads.	Value.	Per cent Lost.	Value Lost.
1898	1,103	$661,800	25	$220,000
1899	2,625	1,575,000	20	393,000
1900	1,361	816,600	25	272,000
1901	1,901	1,140,600	30	488,000
Total in four years	6,990	$4,194,000	25	$1,373,000

These figures are, of course, only estimates, but are believed to be safely on the conservative side and understate the actual loss in fruit suffered in the seasons under consideration.

To the aggregate loss shown in this table of over one and one third million dollars, must be added the loss in value of the fruit grown for canning and drying.

The damage done by the insect is by no means confined to the fruit, but great injury is at times also done to the trees themselves. The insect feeds in the spring upon the new growth as soon as it appears, long before the peaches are formed, causing this new growth to die just as it is starting. It is known at this time as the "bud-worm," and its attack has frequently been so severe as actually to cause the death of the infested trees. In parts of California the loss in this way has been in some regions very heavy, but the actual money loss in cases of this kind can hardly be accurately estimated.

In spite of these great losses the peach is considered a very profitable crop in many parts of California, being grown to a considerable extent in the Vaca Valley and adjacent valleys of the foothills of the Coast Range of mountains, in the Santa Clara Valley, and in some of the more favorable portions of the Sacramento and San Joaquin valleys, as well as in the Placer County region, where these investigations were mostly made.

The Placer County peach section, which is probably the best, and certainly largest, green-fruit-producing section in the State, is in the Sierra foothill region, at an elevation of from 600 to 1,200 feet above sea-level. The large proportion of the peach orchards of this section are to be found in the scope of country extending from Auburn on the northeast to Rocklin on the southwest, a distance of fourteen miles along the Central Pacific Railway, and covering the country for from three to ten miles on either side of this railway. Loomis, Penryn, and particularly Newcastle are shipping points in this region.

From the region above described fully ninety per cent of the fresh-peach shipments of the State are made, and the actual loss from the peach-worm here is most clearly felt.

The peach-moth has been long known to entomologists, having been originally described as a European insect in 1839 by C. P. Zeller, in Isis, p. 190. In 1860, Dr. B. Clemens redescribed the moth in Proc. Acad. Nat. Sci., Phil., p. 169, as *Anarsia pruinella*, and in 1872 the same writer identified this insect as the *A. lineatella* of Zeller in "Tineina of North America," p. 36.

Again in 1872, W. Saunders, in Annual Report Entom. Soc. Ontario, p. 15, describes a worm attacking the root and crown of the strawberry, and considers it to be identical with the peach-worm. This belief is shared by other writers, until the work of A. B. Cordley, reported in Bulletin 45, Oregon Agric. Exper. Station, June, 1897, p. 123, made it very probable that the peach-worm and the strawberry crown-borer are distinct insects.

In July, 1872, T. Glover, in Entom. Rec. Monthly Rep., U. S. Dept. Agric., pp. 304–305, reports the peach-worm in Maryland and Virginia.

In 1879, J. H. Comstock, in Rept. U. S. Dept. Agric., p. 255, briefly notes its twig-boring habit and describes the pupation of the second generation on the peach.

The next work of economic importance was that of Edw. M. Ehrhorn, reported by Alexander Craw in Bulletin 67, California State Board of Horticulture, 1893 (1894), page 9; it showed that the insect wintered in the early larval form in chambers hollowed out in the bark of the crotches of the branches of the trees. Mr. Ehrhorn's investigations were continued in 1896–97 by C. L. Marlatt at Washington with material furnished by Mr. Ehrhorn from California, and the results were published in 1898 in Bulletin 10 (new series), U. S. Dept. of Agric., Div. of Entom., pp. 7–20.

The insect has been reported by other writers as being present in Delaware, Illinois, Colorado, and Washington; and doubtless occurs in all peach-growing localities.

The article by Marlatt gives the fullest account of the insect that has yet appeared. This work was unfortunately done under rather unnatural conditions, and does not agree in many instances with the actual orchard habits of the insect here in California. The other Eastern observations were very fragmentary, and required verification here before being of much value as a basis for a scheme of repression.

The writer was somewhat acquainted with the insect from previous studies in the Santa Clara Valley, and from the 2d of January has kept it under continuous observation in breeding-cages, on a large covered tree, and in the orchards in Placer County, particularly about Newcastle, which was headquarters for the investigation. No pains were spared to make the work as exhaustive as possible.

The location of the larger part of the experiments was in an orchard one eighth of a mile southeast of Newcastle, which will be referred to as the *Newcastle station*. Another station was located in an orchard two miles north of Newcastle, which we designate as the *Ophir station;* a third, in an orchard one mile east of Newcastle, known as *station A;* a fourth, in an orchard one and a half miles south of Newcastle, called *station B;* and a fifth, in an orchard three miles northeast of Loomis, and referred to as *station C*. These five places include some two hundred acres of peach trees of many varieties. The number of trees treated in the experiments carried on in these places amount to a total of some 12,000.

The experiments were not confined to these places, however, for work was done in many other orchards. The work done in these other orchards was sufficient to secure some valuable results, and some fourteen of these in which records were kept are reported in the following pages in conjunction with the work and results on the different stations. These other places will be referred to by numbers.

WINTER CONDITIONS, AND WORK OF THE WORM.

The investigation of the peach-worm began by a study of the insect in its winter burrow within the bark, at the crotches of the tree. The position on the tree generally chosen for the purpose is the crotch formed where the new wood joins that of the previous year, though older crotches are occasionally selected. There appears to be something in the physical make-up of the crotch bark that is preferred by the worm for its winter quarters. When the same sort of new bark is formed in other situations, such as that growing over a wound in the older part of the tree, then the worm may also be commonly found in this situation. The position taken in the crotches is that which brings the hibernating chamber invariably on the upper exposure of the limbs. We have never found the burrows on the lower side.

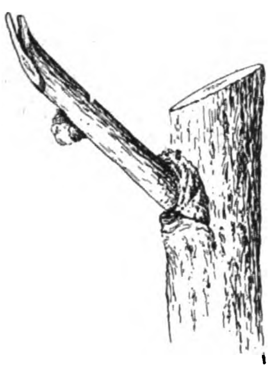


FIG. 1. Twig showing winter burrow, natural size.

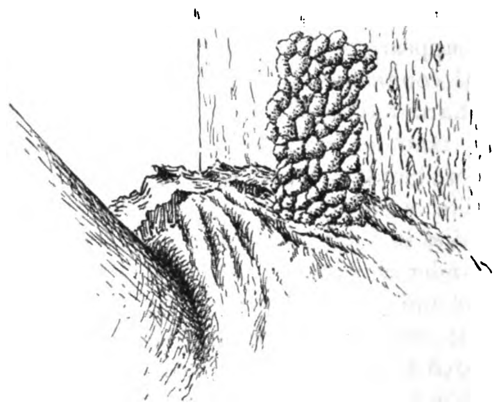


FIG. 2. The same burrow shown in Fig. 1, enlarged.

The location of these burrows may be discovered by the presence of a small mound, which is in reality a silken tube covered with a complete, closely-arranged covering of minute pellets of masticated bark. The color of these pellets on a recently constructed tube is a reddish-brown, of the same shade shown by the bark some hours after it has been cut, and changes to a darker brown after continued exposure to the weather. These mounds are completed in the fall preliminary to the worm's going into winter quarters. They are not added to, nor increased in length, during the winter, even where we have carefully clipped away the tube. Several such uncovered burrows were kept under observation from January 3d to March 5th without any additions being made. The worms on this latter date were removed and found to be alive and apparently healthy. The pellet-covered tubes, shown in natural size in Fig. 1, are rather minute and will usually escape notice. They are quite characteristic in form and are easily recognized in any of their modifications by the aid of a glass, when the bead-like arrangement of the pellets on the tubes, as shown in Figs. 2 and 3, will be noted. The hibernation burrows are cut out well beneath the bark, and extend into the cambium layer. In the majority of cases they are found just beneath a thin layer of the greener cells below the brown bark, while the greater part of the burrow is in the yellowish portion of the cambium. The burrow is generally about three times as large as the worm occupying it, and is lined with silk. The silken tube previously referred to, which projects from the mouth of the burrow, is an extension of this lining. This silk-lined chamber is very efficient as a protection from all inclemencies of the weather, and likewise protects the worm from sprays in a remarkable manner, as will be seen from the experiments detailed later on.

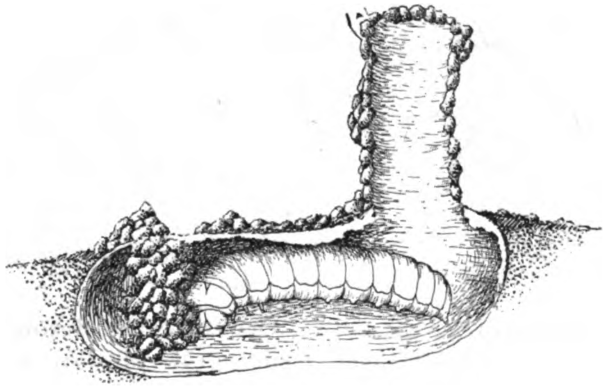


FIG. 3. The same burrow laid open, showing how the worm begins its spring work.

Hibernating Larvæ.—The hibernating larvæ occupying the silk-lined burrows are commonly found at the deep end of the chambers with their heads toward the silken tubes, though they may be found in almost any position. Their age, as they were found in January, is not known, though there was some variation in size and two stages of growth were present, judging by the sizes of the heads. These hibernating worms ranged from 1 to 1½ millimeters* in length. The abdomen and thorax varied in color in different specimens from light brown to white, the head and cervical and anal plates being a shining black, in sharp contrast to the rest of the body. The space between the second and third thoracic segments is noticeably and characteristically lighter in color and more evident than that between any of the other segments. The creature is ornamented with hairs, which spring singly from minute

*A millimeter is equal to $\frac{1}{25}$ of an inch.

tubercles and which are rather sparsely scattered over it. The general appearance of the larva and the position of the thoracic and abdominal legs are shown, very much enlarged, in Fig. 4. No perceptible change in the size or color of the insect occurred from January 2d until about March 1st.

Parasitism.—The insect was to a slight extent attacked by parasites during the hibernation period, but the amount of benefit derived from this source was extremely small in the Placer County region during the season of 1902. The larvæ of a Proctotrupid fly was found destroying the worms in three different cases, while a predaceous mite, which was probably the same as that mentioned by C. L. Marlatt (Bul. 10, n. s., U. S. Dept. of Agric., Div. of Entom., p. 17) was occasionally noted. The total number of hibernating worms destroyed by these natural

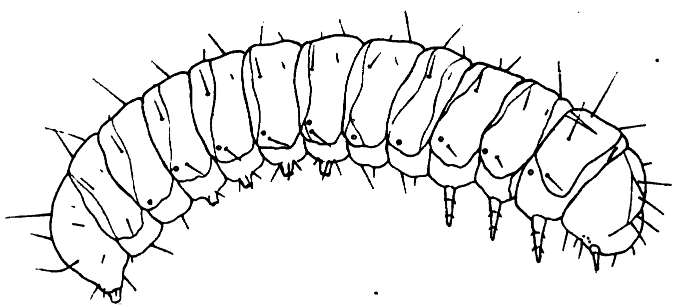


FIG. 4. Wintering larva; much magnified.

enemies was less than one per cent. We were unable, during the season of 1902, to confirm the statement made by Mr. Marlatt in the above-cited publication, that this mite "causes the death of from 75 to 95 per cent of the young larvæ."

DISTRIBUTION OF WORMS IN ORCHARDS.

The distribution of the hibernating worms was very general and uniform over infested orchards, and, except where modified by evident local conditions, the worms were about equally numerous on all the trees. Indeed, as far as hibernation is concerned the variety of the peach seemed of no significance, the worms being found at this season evenly distributed among the early, midsummer, and late trees.

There are some modifying conditions, however, that do result in certain trees being more heavily infested than their neighbors. It is a custom in many orchards to throw out the wormy fruit in piles near the packing-sheds. These sheds are generally placed among the trees, and the piles of rejected wormy fruit are thus usually in close proximity to these trees. It was found that where this custom prevailed these neighboring trees were much more heavily infested than were the rest of the trees in the orchard. This condition is illustrated by the accompanying diagram (Fig. 5), which is of a packing-shed and orchard in the district under investigation. The trees in this orchard are five years old, strong and healthy, but the fruit the previous season was very wormy. The trees generally in this orchard had from five to eight hibernating larvæ in them when investigated.

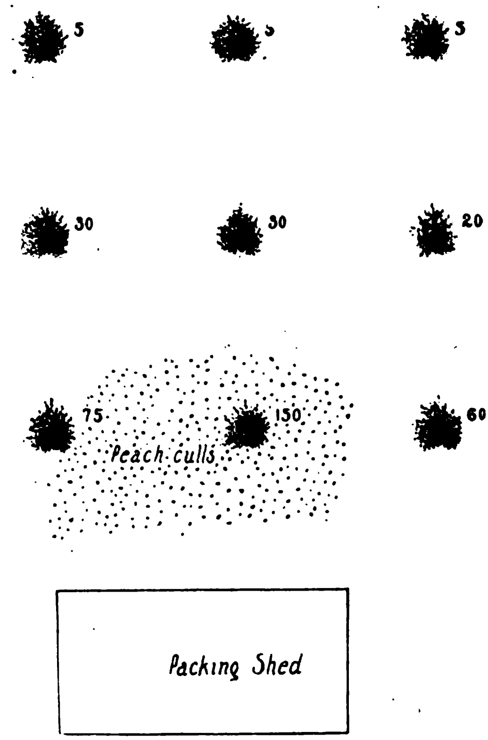


FIG. 5. Diagram of a portion of an orchard showing abundance of worms on trees near cull pile.

The distribution here had been very plainly affected by the local conditions. A similar state of affairs was found to be present wherever similar conditions exist.

In certain orchards it has been the habit to distribute the wormy, unmarketable fruit about the less vigorous trees as a fertilizer. It was found that these trees were infested from five to ten times as heavily as the rest of the orchard.

The practice of allowing the wormy fruit to remain in such a condition that the wo ms may fully develop and carry on the infection could be easily avoided by covering the piles with earth, when the heat developed by fermentation would be sufficient to destroy the worms.

PRUNING AS A CONTROL MEASURE.

Some have supposed that in the process of pruning, many of the worms in their winter quarters were destroyed. The percentage of the worms so destroyed, however, is usually very small, as we have determined in many cases by actual count. This counting of the hibernating chambers in trees before and after the pruning showed, on an average, that generally one worm in ten was cut away. As the prunings are removed from the orchard and destroyed the hibernating worms in them are effectually disposed of, but the destruction of only ten per cent is not a very good degree of efficiency.

No great dependence can therefore be placed in the ordinary pruning as a control for the peach-worm.

WINTER SPRAYING EXPERIMENTS.

The practice usually advised for fighting the peach-worm is to spray the trees in the same way as for scale insects. The field work, therefore, began by an attempt to find the best spraying material for this purpose. A series of experiments was undertaken, with the idea of determining the practicability of killing the insect at this time. These experiments began January 9th, and were continued until past the middle of the month. Kerosene emulsion was the first material tried. The emulsions were made up according to the following formulæ:

1st. 150° kerosene, 1½ pints; sour milk, 1 pint; water, 2 gallons.

2d. ¼ pound hard soap dissolved in 2 quarts of water and 1 pint of kerosene.

Each of these emulsions was diluted with two gallons of water, and infested trees were thoroughly sprayed with these mixtures; but to our surprise, when the worms were examined, to ascertain the results of the treatments, no effect whatever was observable.

Resistance to Penetration.—Upon the failure of the above experiments we began a study in the laboratory. In order to test the penetration of these substances under the most severe conditions, we submerged in the emulsion twigs containing the worms and kept them there two days. When the twigs were taken out after this soaking for forty-eight hours, the worms were found none the worse for the experience. That there might be no doubt as to the killing power of the emulsions used, the material was sprayed on several worms with an atomizer, and these worms were dead in from forty-five minutes to one hour and fifteen minutes. The lime, salt and sulfur spray was experimented with, with exactly the same results; showing the same lack of power to penetrate to the worm in its winter home, but killing readily when it was applied to its unprotected body. The same results were also obtained with the distillate oil (28°) and a number of other sprays used. This whole series of experiments indicated the futility of attacking the worm while the winter conditions prevailed, at least under the conditions found in Placer County.

Winter Spraying.—Notwithstanding the fact that our experiments had indicated the comparative futility of winter spraying as a control for the peach-worm, we made careful observations on the few orchards that were sprayed at this time with the lime, salt and sulfur. The conditions found on these places were similar in character. They were all strongly infested with the hibernating larvæ. The spray material was, in each case, carefully prepared and applied to the trees; the effort being made to cover them completely, so that the treatments should be as effective as possible. The poor results of these sprayings will be seen in the tables on pages 33 to 35, orchards Nos. A, C, 1, 7, 8, 9, and 10. Smaller experiments at the Newcastle station, made so as to keep the trees under closer observation, gave exactly similar results.

Besides this work with the lime, salt and sulfur, we sprayed, early in February, six trees (three Hales and three Salways) at the Newcastle station with kerosene oil emulsified with soap in the proportion of 1 part of the emulsion to 8 parts of water on one tree of each of these two varieties; the same emulsion in the proportion of 1 to 10 on two of the other trees, and a mechanical mixture of kerosene oil 1 part to water 3 parts on two more trees.

And also at the Ophir station we sprayed, in the middle of February, forty-eight Salway peach trees with the so-called Hercules emulsion of 28° distillate oil, using the proportions 1 part of emulsion to 8 parts and to 12 parts of water.

In all of these experiments no differences between the sprayed and the checked trees could be distinguished. The account of the ultimate condition is given on page 35.

EXPERIMENTS WITH THE ACTIVE WORM.

Artificially-Induced Activity.—The fact having become thus evident that any work done toward killing the hibernating worm must be delayed, at least until the beginning of the period of its activity, we endeavored to ascertain when this activity could be expected to occur. Branches containing hibernating larvæ were placed with their cut ends in moist sand in a room in which the day temperature was kept at 70° Fahr. and the night temperature fell to about 40° Fahr. They were examined from time to time, and by the end of the fourth day an appreciable activity was noted on the part of the worms. Upon opening their burrows at this time they were found to be quite lively in their motions. At the end of the sixth day the worms had begun to tear away the covering portion of the silk lining to their winter homes. On the fourteenth day worms began to come to the surface, and continued to do so for three days, when they had apparently all come out.

To arrive at the effect of continued warm conditions, a number of the chips containing winter larvæ were cut from the trees. The chips were kept steadily at about the body temperature of the experimenter. The effect of this treatment was rapid, as in one case worms had worked their way out of their burrows at the end of the fourth day, and the longest time taken to emerge was six days.

Considering that it was possible that the worms might be brought forth from the winter quarters by exceptional warm temperature conditions occasionally occurring during the winter, some of the worms were kept under observation after they had come to the surface, to determine if they would, in the absence of green food, re-imbed themselves. A number of these worms, and also a number that had been cut from their burrows, were placed upon fresh uninfested twigs, and their actions noted. During the first twenty-four hours the worms were all more or less active and restless, moving about a great deal, but with no apparent definite object. They became less active during the second twenty-four hours, but made no effort that could be recognized as an attempt to make new burrows. A progressively diminished activity continued during the third twenty-four hours and during the remainder of the time of the experiment, the worms finally dying without re-entering the bark. This experiment was carried on in duplicate, one set being under natural temperature conditions, and the other in a room where the temperature varied between day and night from about 70° Fahr. to about 40° Fahr. The results were the same in both sets. These experiments would seem to indicate that if continued warm weather prevailed during the winter, numbers of the worms might come to the surface, and in the lack of the necessary food would perish.

Experiments in Penetrability.—A series of experiments as to the penetrability of the winter quarters of the worms, after the worms had become active under the influence of an elevated temperature, was now undertaken. The sprays were the same as those previously described, and the work and the results are shown in the following tables:

TABLE SHOWING EFFECTS OF SPRAYS ON WINTER QUARTERS OF THE WORM.

After 6 Days of High Temperature.

Spray Used.	Effects at End of—			
	1 hour.	2 hours.	3 hours.	4 hours.
Kerosene and milk emulsion	Alive	Alive, feeble	Feeble	Dead
Kerosene and soap emulsion	Alive	Alive, feeble	Dead	.....
Distillate emulsion	Alive	Alive, feeble	Dead	.....
Lime, salt and sulfur	Alive	Alive, feeble	Dead	.....

After 8 Days of High Temperature.

Kerosene and milk emulsion	Alive	Alive, feeble	Dead	.....
Kerosene and soap emulsion	Alive	Alive, feeble	Dead	.....
Distillate emulsion	Alive, feeble	Dead	.....	.....
Lime, salt and sulfur	Alive, feeble	Dead	.....	.....

The results obtained in these experiments seemed definite enough to prove that spraying operations against the peach-worm, to be successful, should be delayed until such time as the worm became active. Growers were therefore advised to delay their spraying operations until the worm had eaten out of its winter nest upon the coming of the warm-weather conditions of spring.

SPRING CONDITIONS AND WORK.

The next stage in the investigation was the planning and carrying-out of extensive field tests, based on the observations and experiments just described.

SPRAYING EXPERIMENTS.

The experiments undertaken at this time were of two classes—those with lime, salt and sulfur mixture, and those with oils and emulsion. Of the former there was a large series under the direct supervision and control of the writer, and a much larger amount of spraying was done by farmers in accordance with our advice. Fully eighty per cent of the spraying done in Placer County this year was timed according to these directions.

In the orchards of the five stations established for this study some 12,000 bearing peach trees were sprayed with the lime, salt and sulfur compound. As full records as possible were kept of the spraying in the whole region where the investigation was made, which amounted to over two million trees which received this same treatment.

Spraying was done at this time on five different places with the I X L compound, a proprietary preparation quite widely advertised. These places, which will be referred to as Nos. 2, 3, 4, 5, and 6, were treated with the compound named, following the exact directions given for the work by the manufacturers. The material was first applied just as the buds were bursting, and this was followed by another application about one month later. Altogether some 8,300 peach trees were sprayed on these five places with this compound. A close watch was kept on these orchards, for it was felt that if the material, which contains lime, salt and sulfur, would control the worm, the fact that it can be purchased ready-made and comparatively cheap would be much in its favor. The results, however, were very unsatisfactory, as will be seen below.

We experimented also with distillate oils, both in mechanical mixture with water and in emulsions. A number of these oils and emulsions were furnished us by the Densmore-Stabler Refining Company of Los Angeles for the purpose of experimentation. These were the 28° distillate treated and untreated, and the 33°–35° distillate and emulsions made up from these oils.

Danger to Blossoms.—All this spraying in the orchards was timed as far as possible by the condition of the trees; that is, it was done generally just before they burst into blossom. In very many instances the spraying could not be done until the trees were in full bloom. It has not usually been thought possible to spray when the blossoms were out without seriously injuring or killing them, especially with a spray of this strength.

Spring spraying must be done nearly at blossoming time, and may easily be delayed by various causes until the trees are in blossom; much attention was therefore given to the danger of injury by spraying while the trees were in bloom. The blossoming dates for 1902 of the various varieties of peaches grown in large quantities in the Placer County district are given in the following table. The varieties are arranged in approximately their ripening order:

BLOSSOMING PERIODS OF PEACHES.

Variety.	First Blossoms.	Full Blossoms.
Alexander	March 15	March 20
Hale	March 15	March 20
Triumph	March 16	March 21
Imperial	Feb. 25	March 2
St. John	Feb. 24	March 1
Early Crawford	March 10	March 15
Foster	March 5	March 12
Susquehanna	March 5	March 12
McDevitt	March 2	March 8
Levi	March 13	March 18
Salway	March 15	March 20

The large experiment was with one lot of some two hundred Hale trees at the Newcastle station, which were sprayed with the lime, salt and sulfur compound on March 17th and 18th, just as the trees were nearing the period of full bloom.

This is a variety that exhibits a strong tendency to drop the buds in the spring, yet the trees that were sprayed when in blossom set fruit quite as freely as the unsprayed check trees in the neighborhood, and also as did the trees that were sprayed earlier in the season.

Of course, some blossoms were injured by this treatment, but absolutely no commercial damage was done, and the fruit on these trees was evenly distributed and had to be thinned. The injury to blossoms apparently occurred only when a fully open blossom stood in such a position as to be filled by the spray and to retain this material in the cup. This combination of conditions, however, existed in so few cases that the number of blossoms that were killed by the spray was exceedingly small. A tree will have blossoms in all conditions from the swelling bud to the fully open flower, and if the latter had been all killed it is possible that there might be no real loss.

The effect of the atmospheric conditions was seen very clearly in a portion of this experiment. During a few hours of the time when this work was being done the atmosphere became extremely dry, because of a north wind. The trees sprayed during this time lost a much larger number of blossoms, and tender twigs were also killed. No damage, however, occurred when the usual moist atmospheric conditions of this season of the year prevailed. Our experience this season has indicated that the blossom of this variety of peach is more susceptible to injury by spraying than is the case with any other; and only during the time drying winds are blowing need there be any hesitancy in spraying, even though the tree is in bloom.

The latest spraying in the experimental orchards on Early Crawfords was March 5th and 7th, a few days before the first blossoms appeared, but after the buds were beginning to burst. No trace of injury was observed. Some Fosters were sprayed on March 1st, and others on March 5th and 7th. On the latter date, one of the trees that was nearly in full bloom, having a large number of fully opened flowers on it, was sprayed with especial pains and thoroughness, completely drenching it with the spraying material, in order to produce injury, if possible. A careful watch was kept of this tree, and the actual loss to it, so far as could be made out, was eleven blossoms. The tree in question is fourteen years old, and had many hundreds of blossoms out when the

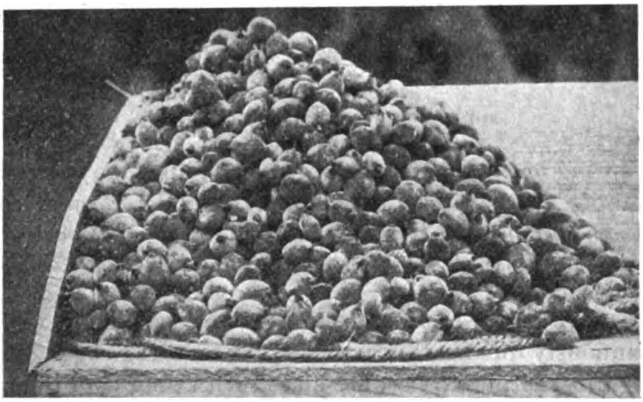


FIG. 6. Fruit from thinning of Foster tree sprayed when in full bloom.

spraying was done. So much fruit set on this tree that heavy thinning-out had to be done late in April, when 1,635 peaches were taken from it, leaving still a good crop on the tree. (See Fig. 6.)

A number of Susquehanna trees were sprayed on March 12th, 13th, and 14th, just when they were in full bloom; no apparent damage was done to the flowers, and the fruit required very heavy thinning.

Spraying was done on a number of the McDevitts on the 11th of March, after some of the blossoms had fallen, and again no damage was done.

These experiments were practically duplicated in many different orchards, and the same results were obtained in each case. It can thus be safely said that late spraying with lime, salt and sulfur, under the conditions obtaining in Placer County, does not in any appreciable way affect the crop, provided the spraying is not done when the atmosphere is extremely dry.

Our work with *oils and emulsions* began on March 31st, when the trees had begun to set fruit and most of the blossoms had fallen. Enough of these remained, however, for us to see the effect of the materials used on the flowers, and some slight loss of fruit through burning of the blossoms was shown. This burning was quite as evident when the emulsions were used as weak as one part of the emulsion to fourteen of water as when the distillate oil was used in the proportion of one of the oil to three of water. Altogether one hundred and sixty-eight Salway peach trees were sprayed with these materials.

We also experimented with the so-called *Hercules emulsion* of 28° distillate oil, spraying fourteen Salway peach trees on March 22d with this preparation, used in the proportion of one to ten of water. At this time the trees were just past full bloom, and the spraying resulted in considerable loss, on account of the blossoms being scorched. Fully one fifth of the blossoms on these trees were destroyed by the spray.

SPRING HISTORY OF THE WORM.

As the spring opened it became possible to follow the beginning of the spring activity as it occurred in the orchard under normal conditions.

The worms remained inactive in their burrows until early in March, when they began to work their way out.

Escape from Burrow.—The process of leaving the burrow was observed very continuously during this time in the breeding-cages, where twigs containing hibernating larvæ were placed with their ends in moist sand; on the net-covered tree, where one hundred and thirty-five worms were under observation; and also in the orchard trees, where perfectly natural conditions were found. These three sets of observations gave results that tallied in all particulars. It was found that when the warm-weather conditions had prevailed to a sufficient extent to make the sap begin to flow appreciably in the tree, then the worms also became active and began to work their way out of their winter burrows.

Their first efforts to obtain this end consisted in a tearing away of the silk lining of the burrows. This tearing-away process began with the removal of the floor portion of the lining, and continued until about two thirds of the covering portion had been removed. While doing this the worms first fed on the tender tissues of the bark beneath the original burrow, but after a few days they began to eat their way toward the surface, filling the burrows behind them with excrement. They usually reached the surface in from ten days to two weeks. During this time a considerable increase in size could be seen, and also a marked change in color, the worms becoming of a much darker shade.

Attack on Buds.—The worms when they appeared on the surface were from 3 to 4 millimeters in length. These worms spent the first two or three days after leaving their burrows wandering about on the bark of the tree. They then attacked the young growth and bored their way into the pith of the starting bud, either from the side or at the tip, the latter being the point most generally chosen.

Frequently the worms contented themselves with merely boring into the pith from the side and then withdrawing and attacking some other shoot. The twig so attacked was so weakened at the point where entry was made that the portion above the wound soon died away. One worm might attack many buds in this way and the injury to the tree be multiplied. The worm, again, frequently bored its way into the pith of the chosen shoot and then took a downward course, eating away all of

FIG. 7. Wilting following attack of bud-worm.

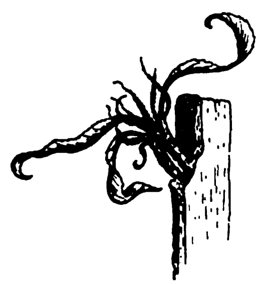


FIG. 8. Section of twig, showing burrow made by bud-worm.

the twig save a mere shell of bark and fibrous material on the outside of its burrow. This burrow was partly filled with excrement, but at no time did we find a burrow sufficiently filled with voided material to interfere with the ready passage of the worm up or down. The worms might attack a number of twigs in this way, and here also the injury that a single worm might do was multiplied. The twig that is attacked very quickly wilts and dies, and this wilted appearance of the twigs is a good indication of the presence of the worm at work in the tree. Indeed, the work done by the worm at this time and the after-appearance of the twig are quite characteristic and easily recognized. In Fig. 7 is given a good illustration of this work of the "bud-worm," as the creature is known in this stage of its life, and the wilted appearance of three or four leaves above the point where the worm is at work can be seen. Fig. 8 shows a section of a newly-started twig, down which a worm had burrowed its way until it had reached the old and hard wood.

Again, in Fig. 9 can be seen a photograph of, first, a twig which had not been attacked at any time by the "bud-worm," and then of several on which the attack was very severe. It will be seen from these illustrations that the work of the "bud-worm" may result in very serious consequences to the tree as well as to the crop, if not actually threatening the very existence of the tree itself. In many instances of the bud-worm work that came under observation this season, the tree appeared as though burned by fire.

The attack of the bud-worm is generally more to be noticed and feared on young trees than on older ones. We have found that three or four worms could completely destroy a three-year-old tree, and while this attack on an older tree would be serious, yet it would not be fatal.

FIG. 9. Results of bud-worm attack, shown in the six twigs on right. Left-hand twig has not been attacked.

The most serious work of this kind is in newly-placed grafts and dormant buds, which are very frequently attacked and destroyed.

The work of the worms in the buds and new twigs continued until pupation was first observed in the latter part of April. The full-grown larvæ at this time were about 10 millimeters in length and the general color quite dark, the characteristics as shown by the young larvæ remaining almost unchanged.

RESULTS ON BUD-WORM OF EARLIER WORK.

Our first comparisons of the effect of the spraying experiments were made possible when the bud-worm work began to be evident, which was in the latter part of March and early in April. At this time it was found that the worms were very plentiful all over the district on such trees as had not been sprayed at all. From one of our check-trees at the Newcastle station we cut out eighteen bud-worms, and the average number on some forty unsprayed trees on this place was eleven worms. The same heavy infestation was shown at the Ophir station also, while from one unsprayed tree at station A we removed twenty-three bud-worms. Check-trees at stations B and C were also badly infested; while the unsprayed orchards generally were infested at the rate of from two to ten worms to the tree. The number of bud-worms found on the check-trees through the whole district indicated that the season was a favorable one for the peach-worm.

On sprayed trees, using the same bud-worm basis of computation, we found that where the IXL compound had been used no control of the worm whatever had been obtained. The trees on places 2, 3, 4, 5, and 6 were as badly infested with the bud-worm as though no spray at all had been used, and from five to twelve worms were cut from many of the trees on these places. Some of the trees, and this especially on place No. 6, appeared as though burned, as the result of the work of the bud-worm. No "curl-leaf" was noted among these trees, and their general condition, other than the effect of the bud-worms, was fair.

The trees which had been sprayed with the distillate oils and emulsions showed a very much lighter attack of the bud-worms, for among these trees it was found that the average number of bud-worms was from one to two to the tree; while from the check-trees, unsprayed, on the same orchard, we cut from eight to twelve bud-worms. These oil-sprayed trees were affected with "curl-leaf" quite severely.

The lime-salt-and-sulfur-sprayed trees, when the spraying had been done in the early spring, showed the most satisfactory results of any at this time. On the various station orchards, comprising over 12,000 peach trees, the average number of bud-worms was about one to every ten trees, and this average was maintained on many other orchards in the district. Indeed, it was a difficult matter to find the worms in these orchards, and it was only by the closest scrutiny of the trees that they could be located in them. The general condition of these trees was excellent and a marked absence of "curl-leaf" was noted.

An examination of the trees in orchard No. 1, that had been sprayed with the lime, salt and sulfur early in February, showed that the attack by bud-worms was severe. On many of the trees from which we cut the worms we found from five to nine to the tree. The general condition of the trees was good and a very small amount of "curl-leaf" was present.

Winter spraying with the Hercules distillate emulsion in February at the Ophir station also resulted in leaving the bud-worms in dangerous numbers. The trees of the kerosene emulsion and the kerosene oil and water experiments at the Newcastle station, which had been winter-sprayed, showed also heavy infestation. Indeed, the condition of these trees was so bad that, fearing the moths might spread from them to the balance of the orchard, all the bud-worms were cut from the twigs.

The following table gives this work and its result in detail:

TABLE SHOWING BUD-WORMS ON WINTER-SPRAYED AND UNSPRAYED TREES.

Variety.	Spray Used in Winter.	Bud-Worms Removed from Sprayed Trees.	Bud-Worms on Unsprayed Check-Trees.
Hale	Kerosene emulsion 1 part, water 8 parts	19	20
Hale	Kerosene emulsion 1 part, water 10 parts	21	20
Hale	Kerosene 1 part, water 3 parts	18	20
Salway	Kerosene emulsion 1 part, water 8 parts	17	16
Salway	Kerosene emulsion 1 part, water 10 parts	19	16
Salway	Kerosene 1 part, water 3 parts	22	16

The Pupa.—The pupa or chrysalis of the peach-moth, shown in Fig. 10, varies from light to dark yellow in color. It is from 5 to 7 millimeters long, and is rather broad in comparison with its length. The segments of the abdomen are well defined, but only the last three are movable, allowing a certain small amount of movement of a twitching nature. The eye spots are of a darker color than the rest of the pupa, and are quite prominent.

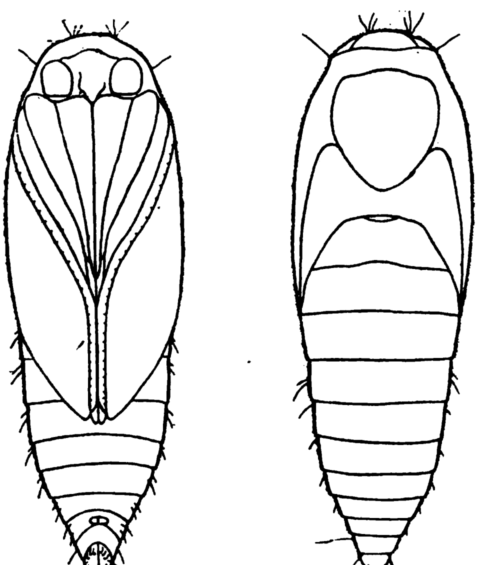


FIG. 10. The pupa. Dorsal and ventral views.

Pupation.— The worms having attained their full growth, withdrew from the green material in which they had been working and crawled down the limbs to the main branches and to the trunk. Here the rough bark offered many places of scanty concealment sufficient for pupation. The worm, in at least the greatest number of cases, chose for this purpose the hollow formed by the curling-up of small portions of the outer bark. These "curls" of the bark are quite characteristic of the peach tree and are constantly present on the trunk and larger branches. The worms, after crawling into these curls, weave an extremely loose cocoon—a few threads of whitish silk drawn irregularly across the open portion of the curl, and a slight silken carpet, to which the hooks at the end of the abdomen of the pupa are attached, constituting the whole structure. As far as our observations go this is always the method of cocoon-making. This cocoon merely serves to hold the pupa in place, and does not in any other way serve to protect it. In ninety-two per cent of the cases noted the position was well down on the trunk of the tree. In a very few cases the worms pupated in the "curls" of the bark quite well up in the tree, and in only three per cent of the cases noted did pupation take place under broken places in the bark where there is no evident curl. After choosing their pupation places and spinning their slight, web-like cocoons, the worms proceeded to pass into the pupa form, attaining it in from two to two and a half days. Fig. 11 shows the pupation place and the cocoon.

FIG. 11. Pupation place and cocoon.

CAMPAIGN AGAINST THE PUPA.

Two points in this matter of pupation seem of economic importance, and were made the basis of some of our experiments for the control of the worm. Unlike the codling-moth larva, peach-worms crawl down the tree to the trunk, and do not drop to the ground and then crawl to the tree. Secondly, the large majority of the worms pupate on the main trunk of the tree.

These experiments consisted of the use of band traps, and of oil spray on the trunk.

Band Traps.—Since the use of bands as an adjunct to spraying operations in certain cases against the codling-moth is generally recognized as effective, it was thought by ourselves and by some growers that these devices might be of more or less value in the case of this insect, and that it was important to test what value they might have. To determine this point, the following experiments were made: On April 15th, pieces of "sticky fly paper" were placed on the ground close about the trunk of a peach tree, in such a way that a worm coming to the tree would have to cross the paper to get on the trunk. Eleven days later there were seven pupæ taken from the trunk of this tree and not a worm had been taken on the paper. On April 16th paper was placed in the same way about another tree, and fourteen days later twelve pupæ were taken from the trunk of this tree, but not one worm was on the paper. On the 4th of April bands of burlap were put about the trunks and larger limbs of five trees. These trees and the bands were carefully examined from time to time, and four of these trees yielded seven pupæ apiece, yet not one of these was found beneath a band. They were all placed within the "curls" of the bark, as described above, and on the main trunk of the tree. Some were above and some below the band on the trunk. On the fifth tree one pupa out of eight was beneath the trunk band, but in a "curl" of the bark. Paper bands were used, with the same result as when the burlap was used. "Sticky paper" was used as a band in one case in this generation. This paper was placed about the trunk just where the branches began, and on this paper two worms were taken. Seven pupæ were taken in a space of six inches above this band and none below it.

Furthermore, we have observed in four different instances the full process of pupation in this generation, and in every instance the worm crawled down the tree from the green twigs (where it had been eating) to the main trunk, entered one of the "curls" of the bark, and there went through the process. In no case observed did the worm drop to the ground and then make its way to and up the trunk of the tree, and from our observations and from the results obtained from our "sticky paper" and band experiments, we should consider that such a proceeding seldom or never occurs. We could find no warrant for the use of band traps in the campaign against the peach-worm.

Oil Spraying.—Early in May the conditions existing on place No. 2, which is noted as having been sprayed with the I X L compound, were very bad. The attack of the bud-worm was severe on this orchard, and at the time noted these worms had begun to pupate. The pupæ seemed to be quite accessible to sprays in their slight cocoons on the trunk and larger branches, and we determined, with the assistance of the owner, to see what effect spraying with kerosene-oil and distillate-oil emulsions would have on these pupæ. On May 15th and 16th, after a few moths had emerged, but while most were still in the pupa form, we sprayed these trees. The emulsions were made up of the 28° and 33° distillate and with 150° kerosene oil. These emulsions were diluted with water in the proportion of one to eight, and this material was thoroughly sprayed over the trunks and larger branches of the trees. Care was taken not to spray the material on the leaves and new growth, yet some of it did lodge in such positions. Where this occurred the leaves and twigs were badly discolored (yellowed), but in a few weeks they regained their normal color and health. This discoloration occurred quite as much in the case of the kerosene emulsion as in that of the distillate-oil emulsion. Two days after this spraying was done we removed a number of the pupæ from the trees and kept them under observation for four weeks. Moths emerged from two of the twenty pupæ so kept, the rest having been killed by the spray. The ultimate results of this treatment, as shown by the percentage of wormy fruit, will be seen in the discussion of that subject below.

THE MOTH.

The adult moths began to emerge from the pupæ in from ten to twelve days. They are of small size, very delicate, with narrow, well-fringed wings. The color is quite subdued, being a beautiful dark steel-gray in general effect. On closer examination it will be noticed that this general color is relieved by certain darker spots on the fore wings, which are folded over the abdomen when the insect is at rest. The palpi are quite prominent and are usually bent back over the insect's head, having the appearance of horns. The antennæ are very delicate, of a grayish color, ringed with brown, and are laid on the wings when the moth is at rest. The hind wings are much lighter in color and more heavily fringed than the fore wings, and both pairs of wings seem under the magnifying glass to be dusted over with a grayish powder. The length of the moth when at rest is about 7 m.m., and with wings expanded the insect measures 14 m.m. from tip to tip. It differs from other members of the group in certain minute particulars not easy to specify. These other moths are not likely to be found in the same situations, so that the above description will enable one to be fairly certain of their identity.

The moths are very quick in their movements and are easily disturbed, flying rapidly from one place of concealment to another in the orchard.

Lantern Traps.—The value of lantern traps in the war against the related potato-worm, reported in Bulletin No. 135 of this Station, suggested their use in this case also. The traps were therefore thoroughly tested during May, when the moths were on the wing. A number of lantern traps made after the Colorado type* were used. These traps consist of a piece of bright tin made into a funnel shape and opening into a wooden bottle. In this bottle is placed a piece of cyanide of potassium wrapped in paper. Over this a little excelsior (wood shavings packing) is placed. When in use the trap is hung to some tree in the orchard, a lantern is hung just above it, and the poison bottle is slipped over the bottom opening of the funnel. Insects attracted by the light readily find their way into the funnel and then into the poison bottle. Beetles taken thus crawl into the loose packing in the bottle and do not injure the more delicate insects which may be taken and which remain on top. Many specimens of various

* Bulletin 43, Colorado Experiment Station.

genera of beetles were taken, and some moths, a few parasitic hymenoptera, and many mosquitoes (*Culex* and *Anopheles* sp.) were victims of these traps, but we looked in vain for the peach-moth. Not a single peach-moth was taken by these traps during the experiment, in spite of the fact that they were present in numbers in the orchards.

EGG-LAYING.

The moths began egg laying on May 9th. The newly-placed egg is pearly white, and shows under the microscope a rather coarse reticulation. Before hatching the color changes to a deep yellow, almost orange color, and at this stage the egg is quite conspicuous. It is about two fifths of a millimeter in length by one fifth in breadth, being a rather long oval in shape, about twice as long as broad.

FIG 12. Eggs of Peach-moth in position on twig.

These eggs were generally placed in the new twigs near the bases of the leaves, and from one half to two thirds of the distance out from the point of beginning of the twigs. The eggs were placed lengthwise of the twigs, and in a few cases were concealed beneath the bracts at the bases of the leaves. We could, however, note no general attempt at concealment of the eggs under these bracts or spurs, as is recorded by Marlatt (Bulletin 10, n. s., U. S. Dept. of Agric., Div. of Entomology, p. 13), and they were as a rule plainly to be seen. The illustration (Fig. 12) shows the general distribution of the eggs in the neighborhood of leaf bases, some eggs being laid singly and some in loose clusters. They are rather insecurely glued to the surface of the twig.

WORMS OF THE SECOND GENERATION.

Young worms began to come from these eggs on as early as May 19th, the period of incubation being about ten days. The newly-hatched larvæ were about three fourths of a millimeter in length, and did not differ in general appearance from the hibernating worms as described on a previous page.

These worms were restless for the first two or three days of their lives, wandering about on the twigs and apparently doing scarcely any eating.

Finally they would select a place a short distance from the tip of the twig and eat into it at the base of a leaf, bore into the pith, and then follow down the pith in the same manner as the first generation of worms did. This boring process was not observed in any case to extend down the twig more than an inch, and the same worm would attack many twigs. Frequently, also, as in the first generation, the worm would merely bite into the twig a short distance and then withdraw, not having reached the pith. In either case, however, the apparent damage was the same, as the twig died above the point of attack, and some bud below the injury would have to be forced out to take the place of the terminal bud, in order to continue the growth of the twig. This dying-back being entirely at the ends of the twigs, and the leaves soon drying to a pale yellow, rendered this injury quite evident. (See Fig. 7.)

The worms act thus as "twig-borers" for a period covering about twenty days, and then seek the fruit, if any is on the tree. If there is no fruit on the tree, then the whole life of the worm will be spent as a "twig-borer," and the damage of this kind becomes all the more evident.

Attempt to Poison these Worms.—Reports of success by the use of Paris green against the bud-worm indicated a possible means of control. The experimental work was done when the worms of the second generation had begun to appear, which was about May 19th, and the poison used was from samples furnished by the Station laboratory at Berkeley. These samples are designated as Nos. 610 and 611, and the following tables give the method of work and results obtained from their use. The mixtures in all cases were made up with lime in the proportion of 5 pounds to 100 gallons of water. The lime was first slaked and a milk of lime made, and this mixture was strained to remove lumps and grit. The desired amount of Paris green was then made into a paste with water, and added to the lime water in the proportion being experimented with. The atmospheric moisture was determined by a device consisting of a string six feet long, hung in such a way that, while the air had full play upon it, it was in the shade at all times and no wind blew upon it. A light weight was hung to the end of this string. The string would shrink up when the atmosphere was humid, and regain its normal length under dry conditions. This method gave us the comparative humidity only, but this was enough for the purpose.

TABLE OF EXPERIMENTS WITH PARIS GREEN, SAMPLE NO. 610.

Proportions Used.	When Applied.	Atmospheric Humidity.	Condition of Leaves.	Injury to Leaves.	Injury to Fruit.
1-800	May 20, 7 A. M.	High	Turgid	Slight	No fruit
"	May 20, 11 A. M.	Medium	Turgid	Some	No fruit
"	May 20, 2 P. M.	Low	Wilted	Much	No fruit
"	May 20, 6 P. M.	Low	Wilted	Much	No fruit
"	May 27, 7 A. M.	Mod't'ly high	Turgid	Some	In spots
"	May 27, 11 A. M.	Below medium	Sl'tly wilted	Some	In spots
"	May 27, 2 P. M.	Low	Wilted	Much	In spots
"	May 27, 6 P. M.	Very low	Much wilted	Much	In spots
1-1600	May 22, 7 A. M.	High	Turgid	Some	Some
"	May 22, 11 A. M.	Medium	Turgid	Some	Some
"	May 22, 2 P. M.	Low	Wilted	Much	Some
"	May 22, 6 P. M.	Very low	Much wilted	Much	Some
"	May 29, 7 A. M.	Mod't'ly high	Turgid	Slight	In spots
"	May 29, 11 A. M.	Below medium	Sl'tly wilted	Some	In spots
"	May 29, 2 P. M.	Low	Wilted	Some	In spots
"	May 29, 6 P. M.	Very low	Much wilted	Much	In spots

TABLE OF EXPERIMENTS WITH PARIS GREEN, SAMPLE NO. 611.

1-800	May 21, 7 A. M.	Very high	Turgid	None	Slight
"	May 21, 11 A. M.	Medium	Turgid	Some	Slight
"	May 21, 2 P. M.	Low	Wilted	Much	Much
"	May 21, 6 P. M.	Low	Wilted	Much	Much
"	May 28, 7 A. M.	High	Turgid	Some	Some
"	May 28, 11 A. M.	Medium	Turgid	Some	Some
"	May 28, 2 P. M.	Low	Wilted	Much	Much
"	May 28, 6 P. M.	Low	Wilted	Much	Much
1-1600	May 21, 7 A. M.	Very high	Turgid	Some	In spots
"	May 21, 11 A. M.	Medium	Turgid	Some	In spots
"	May 21, 2 P. M.	Low	Wilted	Much	Much
"	May 21, 6 P. M.	Low	Wilted	Much	Much
"	May 28, 7 A. M.	High	Turgid	Very little	Some
"	May 28, 11 A. M.	Medium	Turgid	Some	Some
"	May 28, 2 P. M.	Low	Wilted	Much	Much
"	May 28, 6 P. M.	Low	Wilted	Much	Much

It will be seen that, so far as the apparent injury goes, there was no material difference between the samples used, which were both greens that had passed the California test and were good. In every instance, save one, the material burned the foliage. It will be seen from the table that in the 7 A. M. experiment of May 21st, with sample No. 611, no damage was apparent, so far as the foliage is concerned, and only a slight burning of the fruit. Whatever the reason for this exception, the fact remains that, under the conditions most commonly obtained, there was more or less damage done to both leaves and fruit in all the other experiments. The damage consisted in the entire destruction of the leaves in some cases, in the destruction of the pendent portion of the leaves where a drop of the material gathered in other cases, and in spots being burned in the leaves in still others. The fruit injury consisted generally in the burning-out of spots upon it; and these spots did not develop, but either gave the fruit an unsightly appearance, or decay started in the injured place and the fruit rotted.

The experiments as tabulated were paralleled by another series, in which a spray of water was used before the Paris green mixture was applied, and the tree well moistened. The results in nowise differed from those reported above in detail, which were sprayed in the usual manner. These results were furthermore confirmed on another place near the Newcastle station, where spraying was being done on some pear trees with Bordeaux mixture to which Paris green had been added in the proportion of one pound of the Paris green to 180 gallons of the latter. Two peach trees, four years old and in full foliage, were, by error of the workmen, sprayed with this material. The result was that the leaves and many of the young branches were killed outright.

The experiments with the Paris green were carried no further, as the damage done to the trees and fruit was so great as to render it certain that its use would be wholly inadvisable under the conditions existing in Placer County.

STUDY OF THE FRUIT-WORM.

Early in June the second generation of worms begins operation as fruit-worms. They had been working some time as twig-borers as already described, but for some unknown reason now began to leave the twigs and attack the fruit.

It is in this work in the fruit that the insect does its greatest damage and has attracted most attention. The attack on the fruit is very characteristic, nothing else being mistakable for it.

The worms of the second generation on leaving the twigs bore into the peaches at the stem end in a majority of cases. Not only is the stem end thus generally chosen for the beginning of the attack, but a certain portion of the stem end—the line that is called the suture. After boring through the skin the worm begins to feed upon the tissue of the fruit beneath, often excavating a large chamber, which is more or less filled with gummy matter and excrement. The mouth of the burrow is also generally filled with these materials mixed together.

The skin above the hollowed-out portion of the fruit first turns dark and shrivels up to a certain extent, and finally decay usually sets in. When riper fruit is attacked the worm frequently burrows to and around the pit; and if the latter is split it often attacks the seed.

The worm may, under certain circumstances, make its attack at other points than in the stem end of the fruit. Quite frequently when two peaches are in contact on the tree, the worm bores its way into one of the fruits at this point of contact; or if a leaf or twig touches the fruit, here also the worm may enter. The character of the injury is the same in any of these cases, and the fruit is ruined.

PUPATION.

Early in July the most precocious worms of this generation begin to withdraw from the fruit and to pupate, and this coming-out for pupation continues as late as the last of August before the last of them have completed their work. The position chosen for pupation is in the stem end of the fruit, and usually not the one in which the worm has been working, but often a sound, uninjured one.

The worm lays itself along the suture-hollow in the stem end of the peach, and fastens itself here by two strands of silk, making less

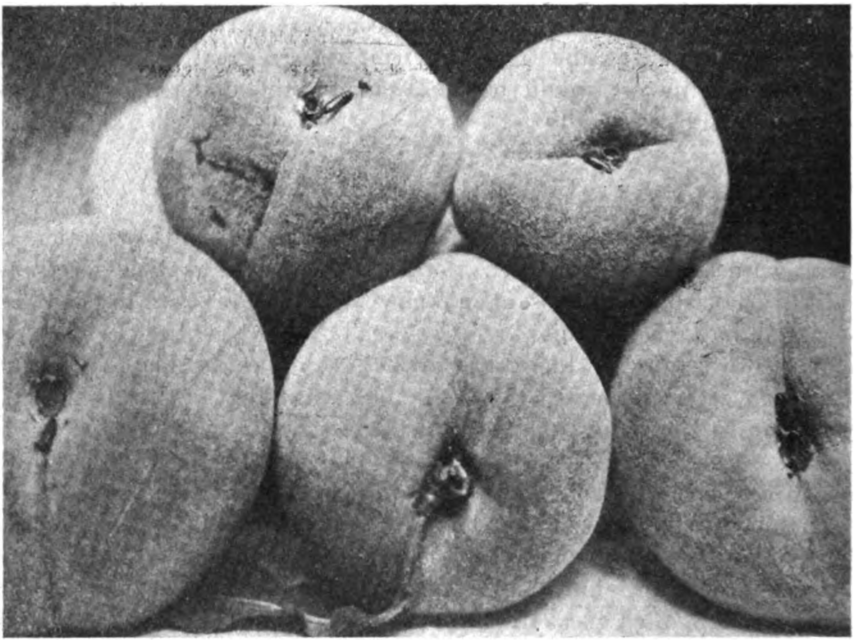


FIG. 13. Pupæ of the second generation of peach-worms in position upon the fruit.

attempt at a cocoon than in the first generation. In from twenty-four to forty-eight hours it passes into the pupa form. Though this is the usual place and method of pupation in this generation, there are a number of other modes. In some instances the worms choose a space between two peaches that lie close together, finding here a satisfactory place of concealment. In a few cases this change took place in rough places on the bark, or under leaves lying against small branches or twigs. In Fig. 13 will be seen pupæ in the positions chosen by the large majority of the worms as described above.

These pupæ do not differ in any way from those produced by the first or winter generation of worms.

THE MOTH AND EGG-LAYING.

The moths issue from these pupæ in seven days, and do not differ appreciably from those of the spring generation. Egg-laying began on the second or third day after emergence, and usually continued for three days. These eggs, which are shown much magnified in Fig. 14, are placed on the edge of the depression where the stem is attached to the fruit; and were not, in any instance noted, placed on the twigs, as are the eggs from the moths of the other generations. The eggs are usually placed singly, and no real grouping of them was seen, though in some cases two or three were found quite close together. The fuzziness so characteristic of the peach seems to render a secure fastening of these eggs impossible, and they could be easily removed from their position.

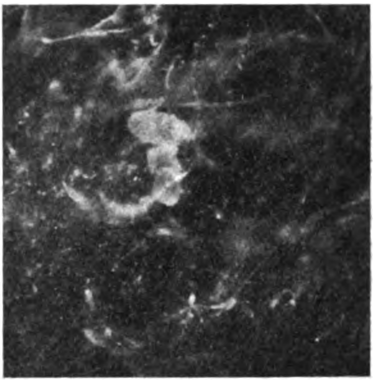


FIG. 14. Eggs of the second generation peach-moth in position on fruit; much magnified.

WORMS OF THE THIRD GENERATION.

The young worms began to appear on the sixth day. They first wandered about on the surface of the peaches for a few hours, and then ate their way into them in much the same manner as the worms of the second generation. The worms of this brood are the only ones that enter the fruit immediately on hatching. They make, therefore, at first very minute burrows, contrasting strongly with freshly-made burrows of the preceding generation.

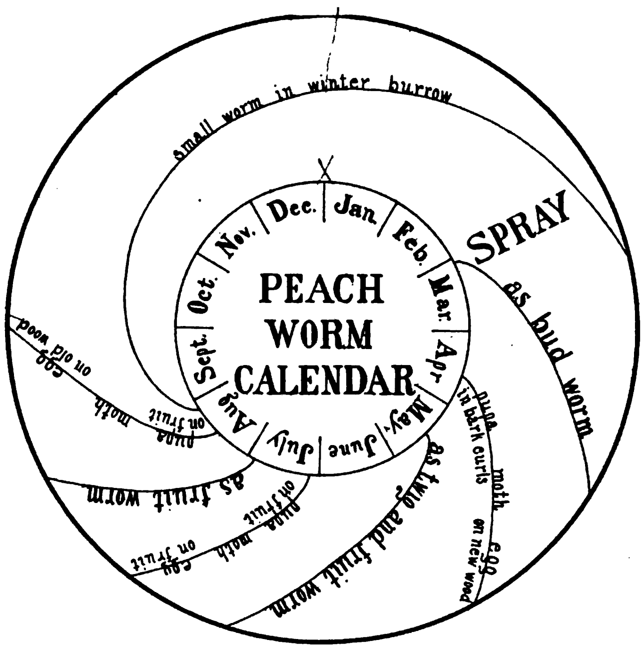
FALL HISTORY OF THE INSECT.

The worms of this generation continue their work in the fruit for about a month, when, their full growth having been reached, they come to the surface to pupate. The method of pupation and position chosen for this purpose differ in nowise from those of the second generation, as described above. About six days were spent in the pupa form, and the moths began to appear about the middle of August.

Egg-laying began in the latter part of August and continued well into September. These eggs were placed sometimes in small cracks and crannies of the bark, and sometimes quite exposed on the bark of the older wood just above the crotches formed by the new wood.

The eggs hatch in about five days, and the young worms, which are from one half to three fourths of a millimeter in length, immediately proceed to bore into the bark of the crotches formed by the new wood with the growth of the previous year, and to prepare their winter quarters. In the region under investigation hibernation was well begun this season on September 1st, and the fully-made chambers, as previously described, could be found readily and in numbers. If the conditions as noted this season are normal, then the worms live in their winter quarters during all of the fall and winter months, remaining quiescent for fully half of the year.

The life history as worked out in this investigation is graphically shown in the accompanying calendar.



RESULTS FROM SPRAYING EXPERIMENTS.

As the summer advanced the work of the worms in the fruit became more and more apparent, until, as the various kinds were picked, we were able to determine the final results obtained through the use of various spray materials. The following table is compiled from the detailed record of the experiments on the five station orchards, and from work done on twelve other selected places on which we took complete records. Only two not-sprayed places are directly referred to, but the heavy loss found on these places is practically the same as found on other places where there was the same neglect of spraying. The percentages of loss were obtained in nearly all cases from actual weights of wormy fruit, though in a few instances the figures represent an actual count of the peaches.

ALEXANDER. Time of first blossoms, March 15.

Designation of Orchard.	Spray Material.	No. Trees.	Time of Spraying.	Per Cent of Loss.
Ophir	Lime, salt and sulfur	50	April 1	1
Ophir	Check trees	4	Not sprayed	50
A	Lime, salt and sulfur	150	March 12	1
A	Check tree	1	Not sprayed	35
B	Lime, salt and sulfur	50	March 10	1
C	Lime, salt and sulfur	275	March 10	3
7	Lime, salt and sulfur	50*	March 8	1
8	Lime, salt and sulfur	100*	March 8	1
9	Lime, salt and sulfur	220*	March 6	2
10	Lime, salt and sulfur	300*	March 10	15
1	Lime, salt and sulfur	110*	Feb. 1 to 6	20
2	I X L compound	300*	March 8	..
2, resprayed	28° dist. emul., 1 to 8 parts water	100*	May 15	6
2, resprayed	33° dist. emul., 1 to 8 parts water	100*	May 15	6
2, resprayed	150° kero. emul., 1 to 8 parts water	100*	May 15	8
3	I X L compound	300*	Mar. 7, Apr. 6	40
3	Check trees	5	Not sprayed	40
4	I X L compound	350*	Mar. 8, Apr. 9	50
5	I X L compound	450*	Mar. 10, Apr. 10	65
6	I X L compound	500*	Mar. 8, Apr. 7	60
11	No spray	400*	....	60
12	No spray	350*	....	55

HALE. Time of first blossoms, March 15.

Designation of Orchard.	Spray Material.	No. Trees.	Time of Spraying.	Per Cent of Loss.
Newcastle	Lime, salt and sulfur	500	March 17, 18	0
Newcastle	Check trees	5	Not sprayed	55
Ophir	Lime, salt and sulfur	200	March 31	0
Ophir	Check tree	1	Not sprayed	40
A	Lime, salt and sulfur	900	March 13, 14	1
B	Lime, salt and sulfur	300	March 10	1
C	Lime, salt and sulfur	550	March 8, 10	20
7	Lime, salt and sulfur	125*	March 8	1
8	Lime, salt and sulfur	150*	March 12	2
9	Lime, salt and sulfur	600*	March 4, 5	14
10	Lime, salt and sulfur	550*	March 12, 13	15
1	Lime, salt and sulfur	220	Feb. 1 to 6	25
2	I X L compound	250*	March 8	..
2, resprayed	28° dist. emul., 1 to 8 parts water	85*	May 15	20
2, resprayed	33° dist. emul., 1 to 8 parts water	85*	May 15	20
2, resprayed	150° kero. emul., 1 to 8 parts water	80*	May 15	25
3	I X L compound	150*	Mar. 6, Apr. 3	45
3	Check trees	5	Not sprayed	40
4	I X L compound	500*	Mar. 7, Apr. 5	65
5	I X L compound	900*	Mar. 7, Apr. 2	70
6	I X L compound	600*	Mar. 3, Apr. 4	60
11	Unsprayed	650*	....	65
12	Unsprayed	800*	....	55

* Approximate.

EARLY CRAWFORD. Time of first blossoms, March 10.

Designation of Orchard.	Spray Material.	No. Trees.	Time of Spraying.	Per Cent of Loss.
Newcastle	Lime, salt and sulfur	1,000	March 5, 7	0
Ophir	Lime, salt and sulfur	200	April 1	2
A	Lime, salt and sulfur	200	March 8	1
7	Lime, salt and sulfur	110*	March 7	1
8	Lime, salt and sulfur	300*	March 6, 7	2
9	Lime, salt and sulfur	125*	March 3	12
10	Lime, salt and sulfur	350*	March 3	15
1	Lime, salt and sulfur	300*	Feb. 1 to 6	18
5	I X L compound	400*	March 3	45
11	No spray	450		45
12	No spray	400*		40
2	I X L compound	130*	March 8	..
2, resprayed	28° dist. emul., 1 to 8 parts water	65*	May 15	25
2, resprayed	33° dist. emul., 1 to 8 parts water	65*	May 15	25

SUSQUEHANNA. Time of first blossoms, March 5.

Designation of Orchard.	Spray Material.	No. Trees.	Time of Spraying.	Per Cent of Loss.
Newcastle	Lime, salt and sulfur	400	March 12	1
Ophir	Lime, salt and sulfur	200	April 1	1
A	Lime, salt and sulfur	150	March 3	3
8	Lime, salt and sulfur	200*	March 3	1
9	Lime, salt and sulfur	250*	March 1, 3	5
10	Lime, salt and sulfur	125*	March 1, 3	15
1	Lime, salt and sulfur	200*	Feb. 1 to 6	25
5	I X L compound	250*	Mar. 4, Apr. 3	30
B	Check trees	2	Not sprayed	50

ST. JOHN. Time of first blossoms, February 24.
IMPERIAL. Time of first blossoms, February 25.

Designation of Orchard.	Spray Material.	No. Trees.	Time of Spraying.	Per Cent of Loss.
A	Lime, salt and sulfur	900	Feb. 21	0
8	Lime, salt and sulfur	500	Feb. 20	2

FOSTER. Time of first blossoms, March 5.

Designation of Orchard.	Spray Material.	No. Trees.	Time of Spraying.	Per Cent of Loss.
Newcastle	Lime, salt and sulfur	450	March 1	1
A	Lime, salt and sulfur	350	March 3	3
8	Lime, salt and sulfur	400*	March 3	2
9	Lime, salt and sulfur	350*	Feb. 28	6
10	Lime, salt and sulfur	400*	March 2	9
2, resprayed	I X L compound	200	March 8	..
2, resprayed	28° distillate emulsion	100	May 16	20
2, resprayed	28° distillate emulsion	100	May 16	20

McDEVITT. Time of first blossoms, March 2.

Designation of Orchard.	Spray Material.	No. Trees.	Time of Spraying.	Per Cent of Loss.
Newcastle	Lime, salt and sulfur	330	March 4	1
Ophir	Lime, salt and sulfur	250	April 2	1
A	Lime, salt and sulfur	400	Feb. 24	2
C	Lime, salt and sulfur	250*	Feb. 27	18
7	Lime, salt and sulfur	150*	Feb. 24	4
8	Lime, salt and sulfur	250*	Feb. 24	5
9	Lime, salt and sulfur	300*	Feb. 23	8
10	Lime, salt and sulfur	300*	Feb. 25	7
1	Lime, salt and sulfur	150*	Feb. 1 to 6	25
11	Not sprayed	400*		50

* Approximate.

LEVI. Time of first blossoms, March 13.

Designation of Orchard.	Spray Material.	No. Trees.	Time of Spraying.	Per Cent of Loss.
Newcastle	Lime, salt and sulfur	650	March 13, 14	0
Ophir	Lime, salt and sulfur	800	April 2, 3	2†
Ophir	Check trees	8	Not sprayed	25
A	Lime, salt and sulfur	200	March 8	2†
B	Lime, salt and sulfur	500	March 8, 10	1†
C	Lime, salt and sulfur	600	March 6, 7	4†
8	Lime, salt and sulfur	300*	March 9	8
9	Lime, salt and sulfur	350*	March 8	4
10	Lime, salt and sulfur	400	March 12	12
1	Lime, salt and sulfur	330	Feb. 1 to 6	25
2	I X L compound	350*	March 7	--
2, resprayed	28° dist. emul., 1 to 8 parts water	125*	May 15	10
2, resprayed	33° dist. emul., 1 to 8 parts water	115*	May 15	10
2, resprayed	150° kero. emul., 1 to 8 parts water	110*	May 15	12
3	I X L compound	250*	Mar. 8, Apr. 2	40
4	I X L compound	200*	Mar. 6, Apr. 4	20
5	I X L compound	350	Mar. 6, Apr. 5	35
6	I X L compound	450	Mar. 7, Apr. 6	40
11	No spray	600*		45
12	Lime, salt and sulfur	450	Mar. 10, 11	4

SALWAY. Time of first blossoms, March 15.

Designation of Orchard.	Spray Material.	No. Trees.	Time of Spraying.	Per Cent of Loss.
Newcastle	Lime, salt and sulfur	500	March 12	1
Newcastle	Check trees	4	Not sprayed	50
Ophir	Lime, salt and sulfur	500	April 4	0
Ophir	Check trees	3	Not sprayed	25
A	Lime, salt and sulfur	400	March 7	2
B	Lime, salt and sulfur	500	March 7	1
C	Lime, salt and sulfur	700	March 5	5
7	Lime, salt and sulfur	300*	March 8	1
8	Lime, salt and sulfur	550*	March 8, 10	2
9	Lime, salt and sulfur	450*	March 4	2
10	Lime, salt and sulfur	450	March 7	5
1	Lime, salt and sulfur	350	Feb. 1 to 6	25
Ophir	Distillate emulsion‡	48	Feb. 12	50
Ophir	Distillate emulsion§	168	March 31	45
2	I X L compound	560*	March 7, 8	--
2, resprayed	28° dist. emul., 1 to 8 parts water	190*	May 15, 16	18
2, resprayed	33° dist. emul., 1 to 8 parts water	185*	May 15, 16	18
2, resprayed	150° kero. emul., 1 to 8 parts water	185*	May 15, 16	18
3	I X L compound	150*	Mar. 6, Apr. 4	30
4	I X L compound	350*	Mar. 6, Apr. 5	25
5	I X L compound	500*	Mar. 7, Apr. 7	25
6	I X L compound	450*	Mar. 7, Apr. 9	40
11	No spray	300*		45
12	Lime, salt and sulfur	500		4

*Approximate. †Estimate.

‡ Hercules distillate emulsion 1 to 8, 1 to 10, and 1 to 12 parts of water, sixteen trees each.

§ Densmore-Stabler untreated 28° emulsion, treated 28° emulsion, and 33° emulsion, 1 to 10 and 1 to 14 parts of water, also treated distillate oil 28°, untreated 28° oil, and 33° distillate, 1 to 3 and 1 to 4 parts of water—fourteen trees each.

UNSPRAYED TREES.

The results obtained in the control of the peach-worm are well shown in these tables. It will be most evident that the season of 1902 was one in which the worms were very plentiful. The check-trees in every case were heavily infested, while the average loss among unsprayed trees indicates the presence of the worms in disastrously large numbers.

Bringing together the unsprayed trees into one table, we see this fact very evident.

PERCENTAGE OF LOSS ON UNSPRAYED TREES.

Variety.	No. of Trees.	Maximum per cent.	Minimum per cent.	Average per cent.
Alexander	760	60	35	48
Hale	1,461	65	40	49
Early Crawford	850	45	40	42
Susquehanna	2	50	50	50
McDevitt	400	50	45	47
Levi	603	50	25	45
Salway	307	50	25	45
Total	4,884	65	25	48

SPRAYED TREES.

The Failure of the I X L Compound.—The same fact is further emphasized in the case of the use of the I X L compound, which proved to be an utter failure as a means of controlling the peach-worm.

PERCENTAGE OF LOSS ON TREES SPRAYED WITH I X L COMPOUND.

Variety.	No. of Trees.	Maximum per cent.	Minimum per cent.	Average per cent.
Alexander	1,600	65	40	53
Hale	2,150	70	45	60
Early Crawford	400	45	45	45
Susquehanna	250	30	30	30
Levi	1,250	40	20	35
Salway	1,450	40	25	37
Total	7,100	70	20	50

These results are very conclusive, both because of the large number of trees concerned, and because the timing of the application was the same as that which gave the best results with the lime, salt and sulfur.

The Use of Oil for Killing the Pupæ.—The results obtained from the use of the distillate emulsions and kerosene-oil emulsions, following the spring use of the I X L compound, indicate a considerable saving over the loss that would have resulted from depending upon that compound. That this result would have been quite as good had the I X L compound spraying been omitted, seems more than probable, when we remember that the bud-worm attack was so severe on the place that it appeared at the time that this material had in nowise controlled the pests in this stage. The results of this work with the distillate and kerosene emulsions were certainly good enough to warrant their use, and will be useful to fruit-growers in the future, if by any chance they fail to spray at the proper time, and find that the worms are pupating in too great numbers on the trunks and larger limbs of the trees, as is their habit in the spring generation.

LOSS WHEN SPRAYED IN MARCH WITH I X L COMPOUND, AND IN MAY WITH EMULSIONS OF DISTILLATE AND OF KEROSENE.

Variety.	No. of Trees.	Maximum per cent.	Minimum per cent.	Average per cent.
Alexander	300	8	6	7
Hale	250	25	20	21
Foster	200	20	20	20
Levi	350	12	10	11
Salway	560	18	18	18
Total	1,460	25	6	15

Winter Spraying with Lime, Salt and Sulfur.—When compared with the loss where no spraying has been the practice, the winter use of the lime, salt and sulfur, as shown on orchard No. 1, results in a certain amount of control of the worm. The results are by no means satisfactory, for while a great deal better than either of the treatments given above, still the work does not result in the reduction of the loss to a low enough minimum.

LOSS WHEN SPRAYED IN WINTER WITH LIME, SALT AND SULFUR.

Variety.	No. of Trees.	Maximum per cent.	Minimum per cent.	Average per cent.
Alexander	110	20	20	20
Hale	220	25	25	25
Early Crawford	300	18	18	18
Susquehanna	200	25	25	25
McDevitt	150	25	25	25
Levi	330	25	25	25
Salway	350	25	25	25
Total	1,660	25	18	24

Spring Spraying with Lime, Salt and Sulfur.—The best results were obtained by the use of lime, salt and sulfur compound, as shown by the following table:

LOSS WHEN SPRAYED IN SPRING WITH LIME, SALT AND SULFUR.

Variety.	No. of Trees.	Maximum per cent.	Minimum per cent.	Average per cent.
Alexander	1,195	15	0	4
Hale	4,175	15	0	5
Early Crawford	2,285	15	0	5
St. John and Imperial	1,400	2	0	1
Susquehanna	1,325	15	1	3
Foster	1,950	9	1	4
McDevitt	2,230	18	1	6
Levi	3,800	12	0	3
Salway	4,300	5	1	2
Total	22,660	18	0	3

In some respects the above table fails to give a correct idea of the results from the use of this mixture at the right time, since it includes two orchards, station C and orchard No. 10, in which the conditions were very unfavorable for producing good results. With these two orchards eliminated, the average amount of injury shown by the tables would not be over one per cent. Even when they are included the efficiency of this treatment as compared with the others is very strikingly shown in the following table:

COMPARATIVE STATEMENT OF LOSS BY DIFFERENT TREATMENTS.

Spraying Material.	No. of Trees.	Maximum per cent.	Minimum per cent.	Average per cent.
Not sprayed	4,884	65	25	48
I X L compound	7,100	70	20	50
I X L compound and distillate	1,460	25	6	15
Winter lime, salt and sulfur	1,660	25	18	24
Spring lime, salt and sulphur	22,660	18	0	3

MISCELLANEOUS RESULTS.

Loss Due to Adjacent Infested Orchards.—The results obtained at station C show plainly the danger from careless neighbors. The location of this station is in a district where spraying is not the rule, and where the loss from wormy fruit is usually very heavy. When the place was selected for these experiments it was found to be well stocked with hibernating larvæ. The orchard had been sprayed the previous year with the lime, salt and sulfur compound. The loss of fruit last year was reported to us as being "very heavy."

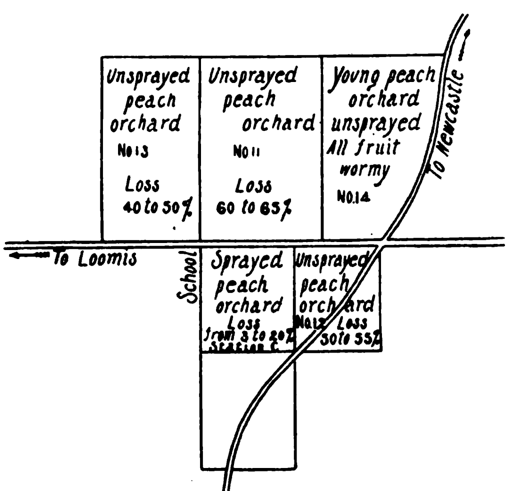


FIG. 15. Loss caused by adjacent unsprayed orchard.

Spraying operations were begun in this orchard when the buds had swollen and were nearly ready to burst out. The lime, salt and sulfur compound was prepared by the owner with great care and the trees thoroughly treated. While the material used and the method and time of application were in accordance with the best practice, yet when the crop was picked it was found that there was a heavy loss from wormy fruit.

The location of this orchard and the relative losses here and in neighboring orchards are shown in Fig. 15. The loss in the sprayed place is very much less, as will be noted, than in the unsprayed orchards, though it is much greater than in the orchards more favorably located as to neighbors.

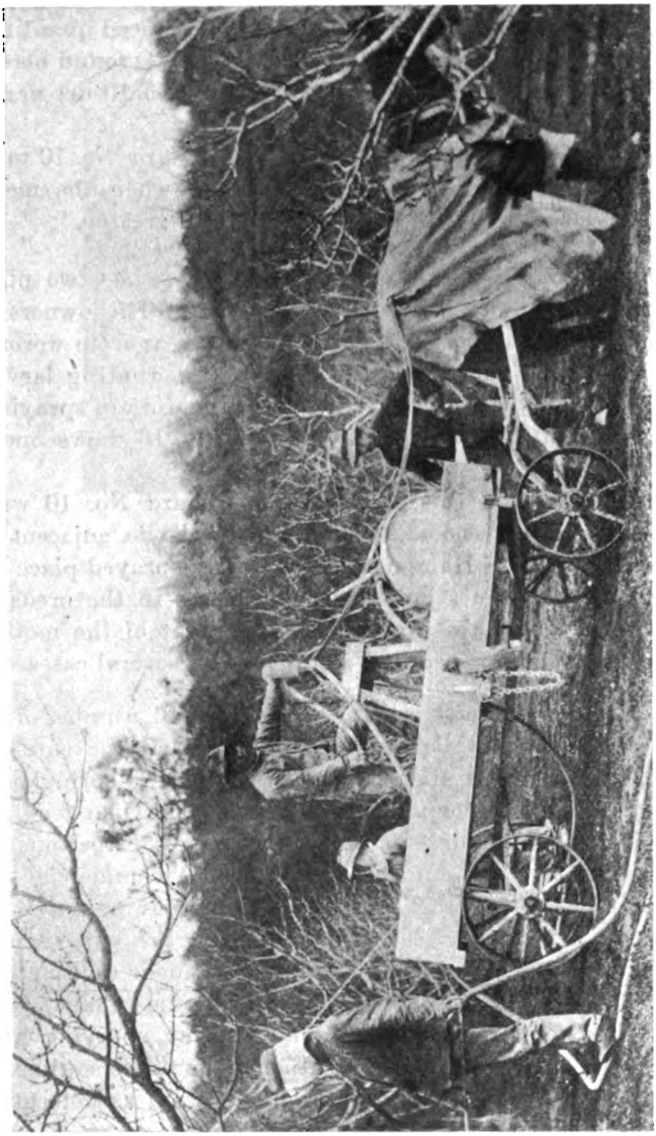


FIG. 16. SPRAYING OUTFIT IN USE AT STATION A.

Loss from Careless Work.—Orchard No. 10 was selected and the records kept because it was a good illustration of the results of carelessly spraying the trees. This orchard was worked by Chinese renters under a lease requiring them to spray the place each year. The work was done, however, in the most perfunctory manner. We visited the place a number of times while spraying was under way, and gave the matter careful attention. The lime, salt and sulfur mixture was used, but was made up in a way that rendered it practically useless. All of the materials, except the water, were being used in reduced quantities, and the mixture was scarcely, or not all, boiled. The loss found here can be directly traced to this carelessness. This orchard No. 10 lies next to the station A, on which the loss was very small.

The tables will show the loss sustained in orchard No. 10 to be considerable, but it would not have been strange, when the method of spraying is taken into account, if it had been still greater.

Saving by Careful Work.—As a contrast to these last two places, we may cite the orchard we have called station A. The owners of this orchard had suffered a heavy loss the previous year from wormy fruit. The trees were found much infested with the hibernating larvæ when inspected in January. We were able to have the work of spraying done in the most careful manner on this place. Fig. 16 shows one of the spraying outfits used at this place.

The contrast between this orchard and orchard No. 10 was very striking. As previously noted, these two orchards lie adjacent to each other. On three rows of Hales next to the poorly-sprayed place the loss was from five to ten times greater than the loss in the orchard as a whole. Without doubt this was due to the flight of the moths from orchard No. 10. Similar instances were noted in several cases.

The Use of Oil and Distillate Emulsion.—A small number of experiments not noted in the above tables indicate that the emulsions of kerosene and the distillate oils, when used in the early spring, produced a good degree of control, though hardly as good as when the lime, salt and sulfur were used under identical conditions. Experiments with these materials are to be conducted, however, on a commercial scale, in order to demonstrate their real value for spring-spraying purposes.

The value of these substances, as used against the pupæ of the first generation, is clearly shown. It should not be made the sole dependence, but rather to enable the grower to have another chance at killing the insect, when for any cause the first, or spring, spraying has been omitted or found ineffective. This treatment should be so timed in the late spring that pupation will be well under way, as determined by careful inspection of the trees at that time.

The distillate oils are prepared in emulsions by certain manufacturers, and are quite cheap and effective. The oils themselves are quite readily emulsified. We have found the following formula useful:

Distillate oil (28° or 33°-35°)	5 gallons.
Common kitchen soap	4 to 6 pounds.

Dissolve the soap in about four gallons of hot water. Pour the oil into the hot suds, and thoroughly churn the two together by pumping the material back into itself through a spray pump. In from ten to fifteen minutes the material will be thoroughly emulsified, and will be of a creamy color and consistency. In this condition it readily mixes

FIG. 17. Boiling the lime, salt and sulfur spray.

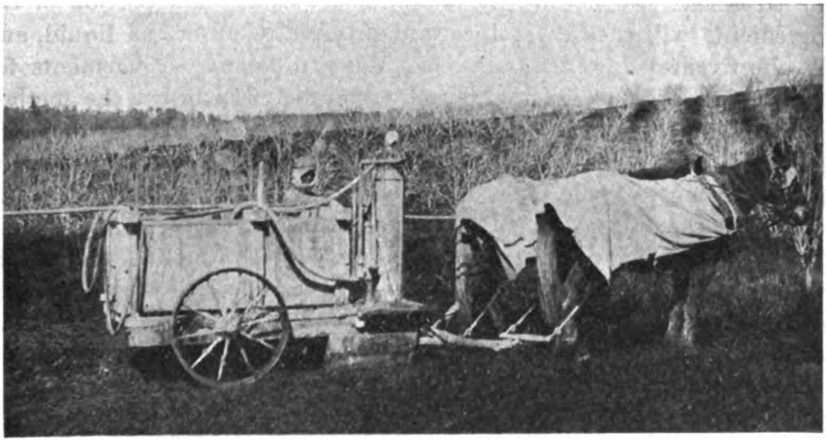


FIG. 18. Wheeled sled and tank spraying outfit.

with water. To use, dilute in the proportion of one of emulsion to eight of water, using hot water preferably. Apply to the trees warm.

The kerosene-oil emulsion may be prepared in the same way, but using no more than four pounds of soap. It is to be used in the same way as the distillate emulsion, but is not quite as effective as the latter.

GENERAL CONCLUSIONS AND RECOMMENDATIONS.

The experiments reported in this bulletin prove that the peach-worm can be controlled by the use of the lime, salt and sulfur compound, if this material is prepared in the proper manner and thoroughly applied at the right time. These three factors are all essential to successful treatment.

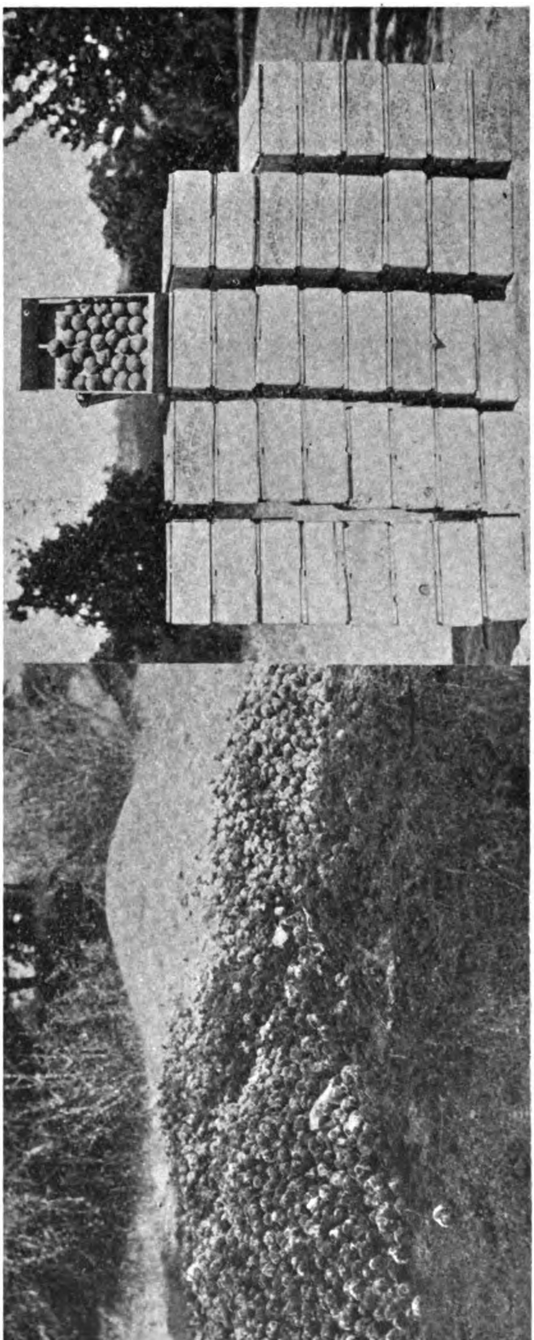
The formula for the preparation of the lime, salt and sulfur spray, as used successfully in the Placer County region this season, is as follows:

Lime	40 pounds.
Sulfur	20 pounds.
Salt	15 pounds.
Water, to make	60 gallons.

Boil 10 pounds of lime and 20 pounds of sulfur in 20 gallons of water for from one and one half to two hours, or until the mixture is a deep amber color, which will indicate that the sulfur is dissolved. The balance of the lime, 30 pounds, should then be slaked in another vessel and the salt added to this latter mixture. This should be stirred until the salt is dissolved and then added to the original mixture of lime and sulfur, and the whole boiled for from thirty to forty-five minutes longer, enough water being added to bring the total amount of material up to 60 gallons. Next strain the material into the spray tank and apply to the trees *hot*. Do not let the material get cold, for a portion of the ingredients will then crystallize and precipitate out of the liquid, and its effectiveness is much reduced. Many different arrangements for boiling the spray are used, and each orchardist will devise the method most convenient to him. We found the device shown in Fig. 17 a convenient arrangement. In this case a large iron cauldron was set up on an iron frame, so made that the bottom of the cauldron was about one foot above the ground, when the device was ready for use. A fire could then be easily built beneath the cauldron and the boiling thoroughly done. When it is not necessary to move the cauldron, it is well to build up a stone or brick fireplace beneath it, so arranged that a good draft can be maintained.

As to the apparatus for spraying, one may employ any of the outfits of pumps, etc., commonly sold for use in orchards. Two such outfits are shown in Figs. 16 and 18, from photographs taken in the orchards this spring.

The important thing in spraying work is to completely cover every tree with the material used. This thorough work must be insisted on as a requisite for successful control of the worm. The hibernating burrows in which the worms are hiding at this season may be found in any part of the tree—from the tips of the topmost branches to the ground.



From unsprayed orchard having seventy five per cent loss.

From well-sprayed orchard having less than one per cent loss.

Fig. 19. Showing Two Ways of Disposing of the Crop.

The *time to make the application* varies with the variety. It should be done when the buds have begun to swell perceptibly, and it may be delayed, without serious injury to the tree, until after the blossoms have begun to appear, at least under the conditions found in Placer County during the past season.

The effectiveness of such treatment can now be considered to be an established fact.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

COLLEGE OF AGRICULTURE
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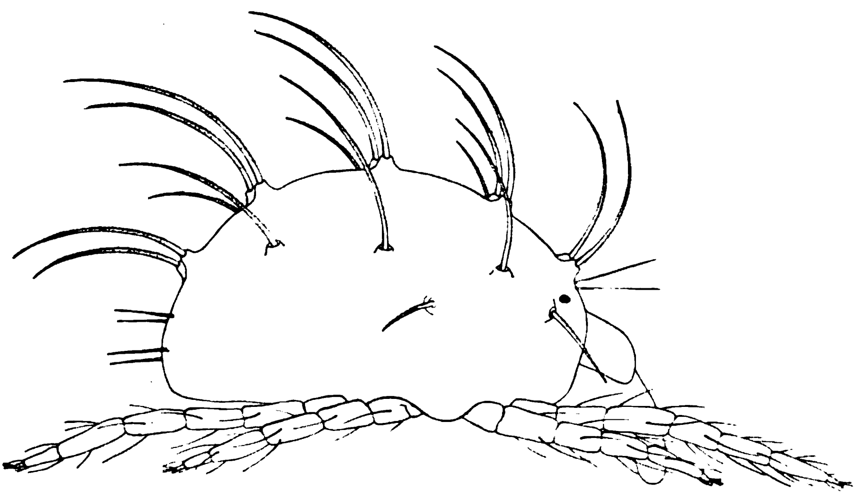
THE RED SPIDER OF CITRUS TREES

BY
C. W. WOODWORTH



THE RED SPIDER

BULLETIN No. 145

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BENJAMIN IDE WHEELER, Ph.D., LL.D., President of the University.

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THE RED SPIDER OF CITRUS TREES.

The investigation of the red-spider on the citrus trees of southern California was undertaken in response to a very urgent request of the Horticultural Commissioners of Los Angeles County, and has been conducted in coöperation with them. A large part of the work was under the immediate charge of Mr. W. H. Volck, a student in the Entomological Department, who was appointed as inspector by the Los Angeles County Board for this purpose. The present bulletin is only a report of progress, since the investigation is still under way and some of the most important facts remain yet to be determined. The season is nearly here for the red spider to resume its injury, and this is published in order to place in the hands of the orange growers the information already accumulated, so that they may make use of it during the present season.

Red spiders have been injurious in southern California for many years, but little attention has been given to the matter, chiefly on account of the extremely minute size of these creatures. During the past shipping season the injury to the fruit caused by the improper use of distillate sprays, awakened more than usual interest in the subject of spotted fruit, including that produced by other agencies. The theory was advanced, and generally believed by the growers, that the red spider was accountable for one of the commoner forms of spotting very prevalent during the past season. The results of the studies made this summer on its habits have thrown great doubt, if not indeed disproved the possibility of this mite producing anything like this kind of injury. There is no doubt that its work, however, has resulted in considerable losses to the growers of oranges and lemons that have not been clearly recognized.

The injuries produced by the red spider are chiefly of two sorts, both dependent upon a diminution of the general health of the tree. The one most readily recognized is the unusual or excessive dropping of the fruit from the trees badly affected. Usually this dropping is not to be attributed to the work of the mite alone, but other things contribute to the result. The other form of injury still more difficult to estimate is the loss which results from the decrease in the size and sugar content of the fruit, that cannot help but occur when the leaves

Fig. 1.

GREEN CLEFT GRAFT.

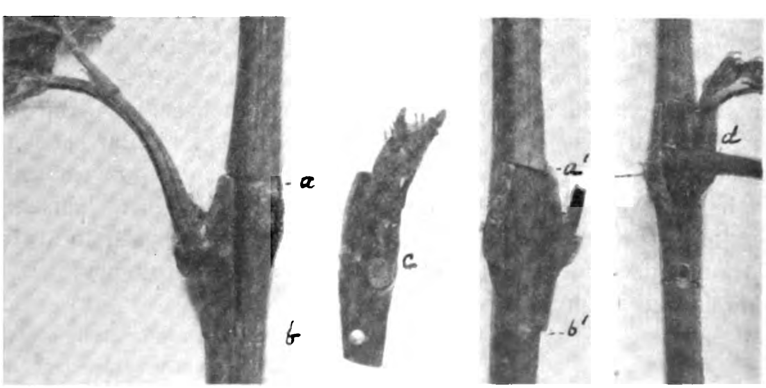


Fig. 2.

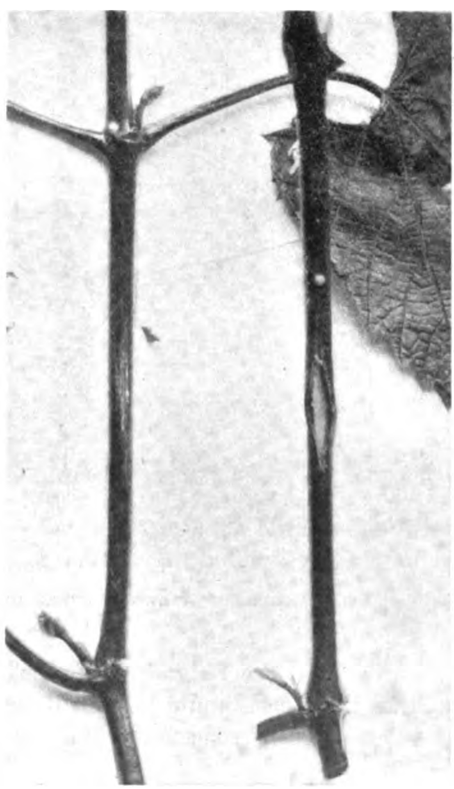
HORWATH GRAFT.

A circular incision, penetrating the whole depth of the bark, is made ⅓-inch above and another the same distance below the bud (*a*, *b*); then on the right and left of the bud two longitudinal parallel incisions are made, joining the annular incisions. The bud thus prepared (*c*) should be placed on a shoot of as nearly as possible the same diameter as that from which it was taken. But the indispensable point, which marks the difference between ordinary budding and Professor Horwath's method, is that the bud must be placed or inserted in place of another bud on a node.

The green shoot to be used as stock having been chosen, and on the latter the bud where the graft is to be made determined, the leaf on that node is removed (*c*). Two semi-annular incisions are made (*a′*, *b′*) at the same distances as on the scion, and a single longitudinal cut is made passing through the bark, dividing the petiole in two and joining the annular incisions. Then with the spatula of the grafting knife the bark is lifted on both sides so as to form two flaps, as in ordinary budding. The flaps being open, the scion is inserted (*d*), the flaps brought over it and the joint ligated. A fortnight or twenty days after, this is cut off. This graft has given good results, but is a lengthy and delicate operation.

Salgues Graft.

The Salgues graft (Figs. 3 and 4) consists of fixing on a green shoot of the year an elliptic scion or shield carrying a bud at its center. It is budding, but so modified as to be considered a new method; the grafts obtained are perfect and the joints invisible except for a slight swelling.

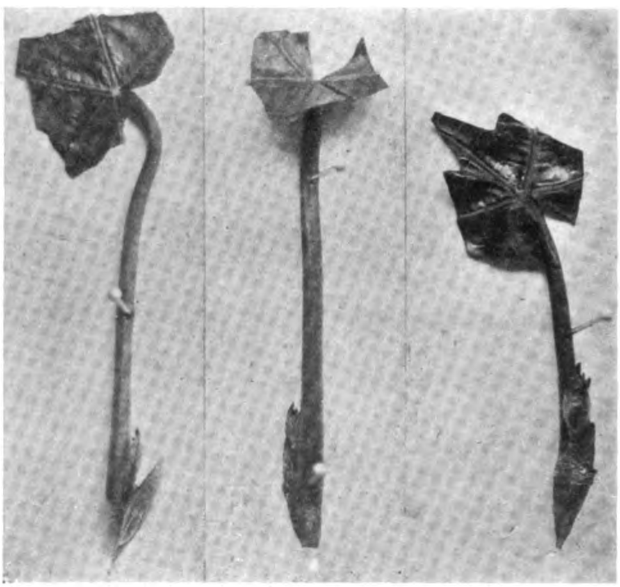


a *b*

FIG. 3.

SALGUES GRAFT. (*Original.*)

On any internode of the shoot to be grafted a longitudinal incision (Fig. 3, *a*) is made with the grafting knife, penetrating the whole depth of the bark and about the length of the shield; with the haft of the grafting knife the bark is raised on both sides of the slit; the shoot is then bent inwards and the lips of the slit open easily (Fig. 3, *b*). The scion bud is inserted and the shoot is left to spring up into its former position. The scion bud is then compressed by the bark, and the operation is completed by tying. The ligature should be removed a fortnight or twenty days afterwards.



a *b* *c*

FIG. 4.

SALGUES GRAFT. VIEWS OF SCION BUD—(*a*) SIDE, (*b*) FRONT, (*c*) BACK.

In order that the Salgues graft may be a success, it is necessary, first, that the stock should be in full sap, so that the lips of the slit may be easily raised; secondly, that the scion bud should be carefully selected.

When a green shoot is cut longitudinally on its entire length, different colorations may be noticed along the section; towards the apex the shoot has not yet begun to lignify, and the section is almost uniformly green in color, only slightly deeper above and below each node. The diaphragm of these can only be detected at the second or third node (counting from the top) by a slightly lighter color. Downwards the diaphragm becomes more distinct; finally, still lower, the pith begins to be indicated by a whitish tint; the scion bud should be taken only from the buds in which the diaphragm is already well apparent, but on the part of the shoot where the white pith is not noticeable. Each shoot will thus give two or three good eyes.

In practice, when one tries to bend a young vine-shoot there is no resistance at the top; then lower down it resists, and still lower down it does not bend but breaks. When the fingers can easily bend the shoot and feel a slight resistance, one is sure that the bud in that region, together with the one above and the one below, are suitable for budding. It is necessary to tie the grafted shoots to a stake, as they are thus better protected and do not dry out as easily as when close to the ground. This graft is simple, gives perfect union, and is getting to be very generally used. It is of great value in reëstablishing vineyards on resistant stock.

The Salgues graft may be performed on mother stocks of American vines through the summer as shoots develop; one can bud sixteen inches apart on the canes with the object of obtaining grafted cuttings for the next season. We have seen contracts given out for this work for $6 a 1000 knitted grafts.

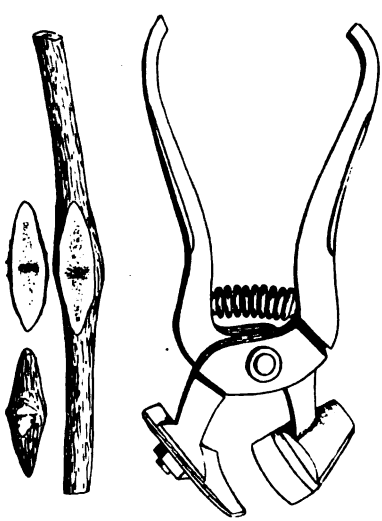


FIG. 5.
BESSON GRAFT.
(*Rev. de Vit., 1894.*)

Besson Graft.

As stated above, the Salgues scion-bud is grafted on the internode of the shoot. The Besson graft (Fig. 5) like that of Horwath, is inserted on the node itself; but while the method of the Hungarian viticulturist is a true budding, that of Besson is an inlaying.

This graft is made in spring, at the same time as the ordinary bench graft. A special pair of shears is used, with curved blades perpendicular to the handle; it cuts and lifts the bud, the same operation being made on the stock and scion canes. The lateral portion detached must be a little under one-half of the thickness of the shoot; the cut is regularly curved and concave, and about one inch long.

On the stock, the second eye,counting from the top of the cutting, is cut out; while for the scion any one of the eyes on the cane is used. The scion-bud fits perfectly, as it is the same blade that makes the two cuts. The cuttings to be grafted should be sixteen inches in length their top being limited by a bud cut half-way through. The graft is tied with raffia, as in other bench grafts. So far, this graft tried on green shoots has not been a success, but on the ripe canes the results have been very good and the quality of the knitting is specially good.

Clarac Graft.

In the Clarac graft (Figs. 6 and 7), as in the Besson graft, a bud is substituted for another bud, but the process differs in many points. To prepare the stock an incision is made an eighth of an inch above a bud (Fig. 6, *a*) and the incision is continued in a straight section parallel to the axis of the cane, penetrating one-third of the diameter; the cut is stopped when the length is a little over the width of the blade

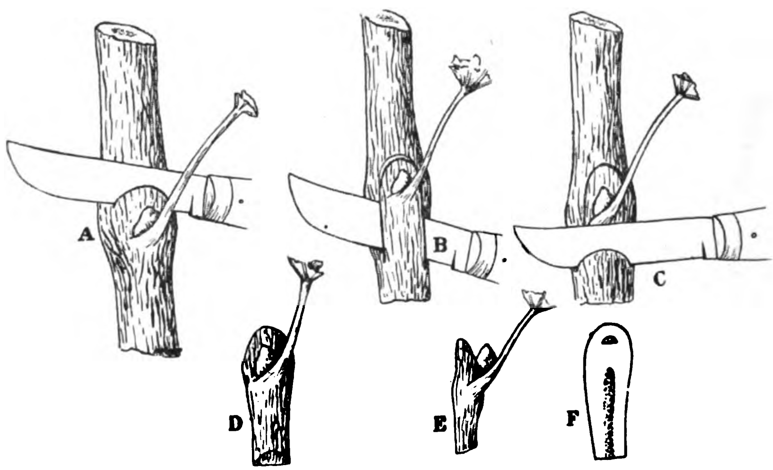


Fig. 6.
CLARAC GRAFT.

under the the base of the bud (Fig. 6, *b*). The blade is removed, laid flat on the cane immediately under the base of the bud, in order to indicate by the width of the blade the point where the new transverse and oblique incision is to be made, to prevent the first section from spreading and to make a strong notch for the scion to rest upon (Fig. 6, *c*).

The scion-bud is obtained in the same way, placed on the stock and tied.

Another way of making the Clarac graft consists in not removing the bud on the stock, only the longitudinal cut being made. The scion-bud is made in the same way but with a longer bevel; it is inserted in the slit prepared on the stock and tied. The bud left on the stock constitutes a sap drawer, which facilitates the knitting of the scion-bud. When knitting has taken place the stock bud is removed.

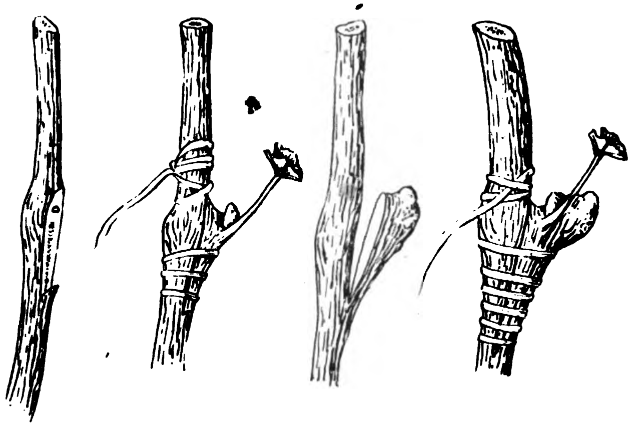


FIG. 7.

CLARAC GRAFT: METHOD WHERE BUD IS LEFT ON STOCK.

(*R. de Vit.*, *1894.*)

The second method is more rapid. In both cases the ligature must be cut away three weeks after being made. Both methods have been successful.

Massabie Graft.

This is practically the same as the Besson graft, but the scion-bud is cut with a special pair of shears.

Vouzou Graft.

The Vouzou graft (Figs. 8 and 9) is a Salgues graft made with an old scion-bud. On a smooth part of the stock above ground a T-shaped incision is made through the bark, and the sides are raised with the haft of the grafting knife.

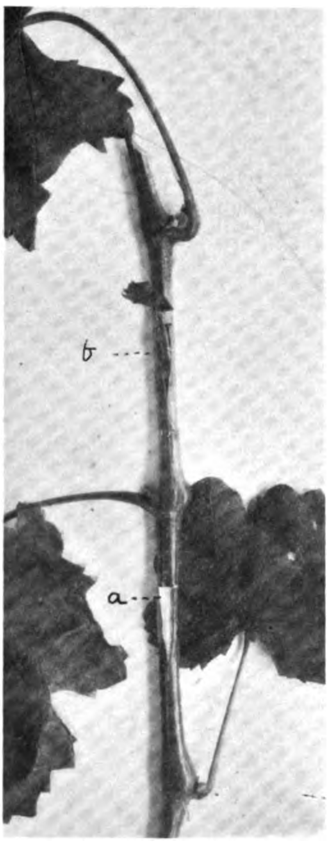


FIG. 8.
AN ORDINARY METHOD OF BUDDING ON A VINE CANE. (*a*) SLIT BEFORE BUD IS INSERTED, (*b*) SAME AFTER INSERTION OF SCION-BUD. (*Original.*)

The scion is taken from a cane of the previous year's growth before the eyes start to burst in the spring, and preserved in sand until the time of grafting. The bud should be well constituted and healthy, but need not be at a particular state of development, as in the Salgues graft. The scion-bud is cut out as is done for fruit trees, but under the eye a thickness of wood is left reaching to the pith; and even a little of the latter may be left. This will give a scion about one inch long, with the inside section nearly flat. The bud is inserted and tied in the usual way. To insure knitting the shoots of the stock must be pinched short; the tie is cut one month after.

This graft may be made during the whole period during which the sap is circulating, and when the bark is detachable from the wood. The Vouzou graft has been very successful; 75 to 85 per cent. of "takes" have commonly been obtained, and in one instance the success of 95 per cent was publicly demonstrated. It is a simple graft and gives a perfect union. In case of failure it is easy to repeat it the same season.

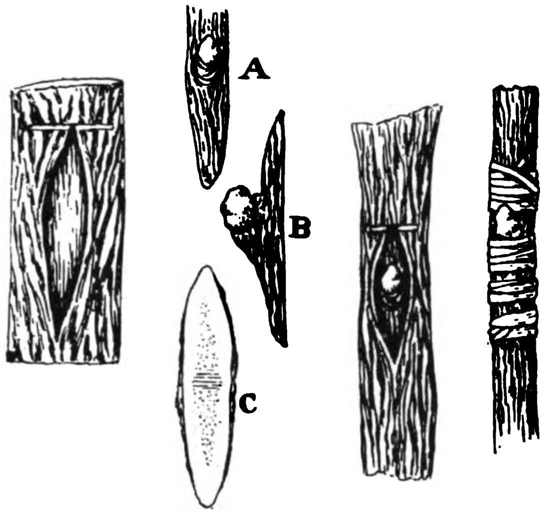


FIG. 9.

SAME AS 8 MAGNIFIED. THE TYING OF BUDS HAS BEEN MADE WITHOUT USING THE FOIL.
(*Rev. de Vit.*, *1895*.)

MEANS OF INSURING THE SUCCESS OF HERBACEOUS GRAFTS.

Selection of shoots bearing buds for scions.—We should always choose branches growing from eyes which would have normally remained dormant till the following season, in preference to branches growing from buds bursting out normally. Shoots of medium or rather small diameter are to be preferred. These shoots will furnish the scion-buds which are to be grafted on the old wood. The diameter of the shoot from which the scion-bud is cut must always be a little smaller than the diameter of those upon which it is to be grafted. The best shoot is that developed in the shade; branches exposed to direct sunlight must always be rejected; the shoot should be light green in color, but not yellow.

The petioles of the leaves of the shoot should be of a whitish-green color, even a little pinkish, slightly transparent at the point of junction with the limb. Shoots bearing leaves with deep green or reddish petioles should be rejected. The eyes of the extremity and base of the shoots, together with those placed at the base of the leaves having a very slender or very long petiole should not be used.

Preparation of Scion-Buds.

The whole of the petiole and part of the limb of the leaf should be left when the leaf is pinched; if the petiole is cut shorter the bud dries out. The same bud may be made with sap-wood or with half sap-wood, the latter is by far the best.

Scion with Sap-wood.—(*a*, *b*, *c*, Fig. 9; *a*, *b*, *c*, Fig. 4). To cut out the shields, the shoot is held with the left hand, the first finger being under the bud; the cut is begun with the base the grafting knife half an inch below the bud; and while cutting, the knife blade is drawn in such a way that the end of the grafting knife will correspond with the end of the section, half an inch below the bud, when finished. This shield will be about 1¼ inches long, and as it will have a chipped edge, it is advisable to smooth it down, which will reduce it to about one inch. The scion-bud is then rather thick in the center and the ends are pointed bevels. The sap-wood of the shield does not knit, therefore it is advisable to diminish its surface.

Scion with Half Sap-wood.—This is far superior to the above. The cut is started in the same way (*a*, Fig. 10), but the knife is drawn parallel to the axis of the cane, as in *b*, Fig. 6. Drawing the blade out the transversal section *bb* (Fig. 10) is made cutting through the bark only.

The bud is seized between the thumb and first finger of the right hand and lifted (*c*) and pulled back (*d*). As the transverse cut only

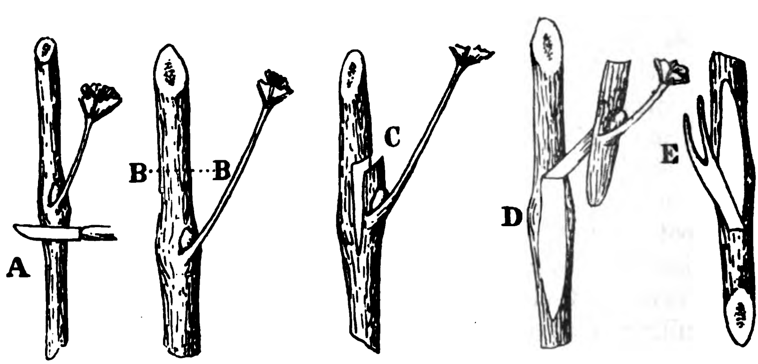


FIG. 10.

PREPARING A HALF SAP-WOOD SCION-BUD.

goes through the bark, in lifting the bud a tongue of sap-wood remains attached to the cane (*d*) and adheres to the scion-bud. When we lift this up it breaks off level with the bud, leaving a two-pronged fork (*e*, Fig. 10). If the fork is not formed, the bud should be rejected, as it is not ripe enough. It is hard to explain this mode of operating, but it is really easy in practice.

Making the Slit on the Stock.—On one- or two-year-old canes, the slit should be made on the rounded part where the bark is thicker and will protect better against desication. However, if the scion-bud has a little sap-wood attached, it is better to place it on the flat side. On old wood the bark is so thin that it is almost impossible to lift it off.

Ligatures.—The best are made out of lead or tinfoil tied with raffia or cotton. The foil is cut into pieces three-quarters to one inch wide and two to three inches long.

Arrangement of Mother Stock.—All shoots of American stock may be readily budded; that is to say a person can place on a vigorous cane from ten to twenty buds and obtain the next season from one vigorous mother vine 100 to 150 grafted cuttings. Long experience has shown that to obtain these results it is necessary to arrange the stocks in the following manner:

Stakes about six or eight feet high are erected ten to fifteen feet apart. As soon as the shoots of the mother stock are about twenty inches in length, eight to twelve are preserved and the balance disbudded. The shoots are tied up in V-shape as soon as hard enough, all auxillary buds and tendrils being removed; this is repeated three times in the season. The even numbered shoots are tied up on one side and those of odd numbers on the other; this facilitates the budding and collecting of the knitted cuttings; twice the amount of wood fit to be budded is obtained in this way. On an experimental plot one hundred 4-year-old Riparia were trellised and as many left without trellising. The first gave an average of 175 feet, the latter 75 feet of wood suitable for budding.

Gathering and Keeping the Budded Cuttings.—We should wait until the leaves have fallen off before gathering the cuttings; they should be cut off on the spot; the whole cane should not be cut off and then the cuttings be removed later, as they are apt to be bruised if treated thus. As the cuttings are gathered, the eyes of the stock are removed, excising them with a grafting knife as closely as possible; those where the buds have missed may be kept to be bench-grafted the next spring. The good ones are placed in cases, in layers separated by fresh moss or moist straw. A lid is placed on the box and the cases are placed in a closed, dry, frost-proof room, and kept until planted. Then the boxes are taken out to the nursery, the cuttings taken out one by one, and their upper end freshened with a grafting knife (not shears), three-fourths to one inch being removed at each end. The cut end is then coated with tar.

UNIVERSITY OF CALIFORNIA PUBLICATIONS.

COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

CULTURE WORK AT THE SUBSTATIONS

1899-1901.

By CHARLES H. SHINN, Inspector of Stations.

BULLETIN No. 147.

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BENJAMIN IDE WHEELER, Ph.D., LL.D., *President of the University.*

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THE FOOTHILL SUBSTATION.

(Five miles from Jackson, the county seat of Amador County, in the Sierra Nevada foothills; highest elevation, 1975 feet)

The last report of work done at this substation carried the history of the place from the summer of 1897 to the summer of 1899, covering two fiscal years. This report covers the period between June, 1899, and June, 1901, with some items, such as rainfall, continued to the latest date available before publication.

The foothill substation, while, as always, difficult of access and supervision, on account of the distance from the railroad, which must be left

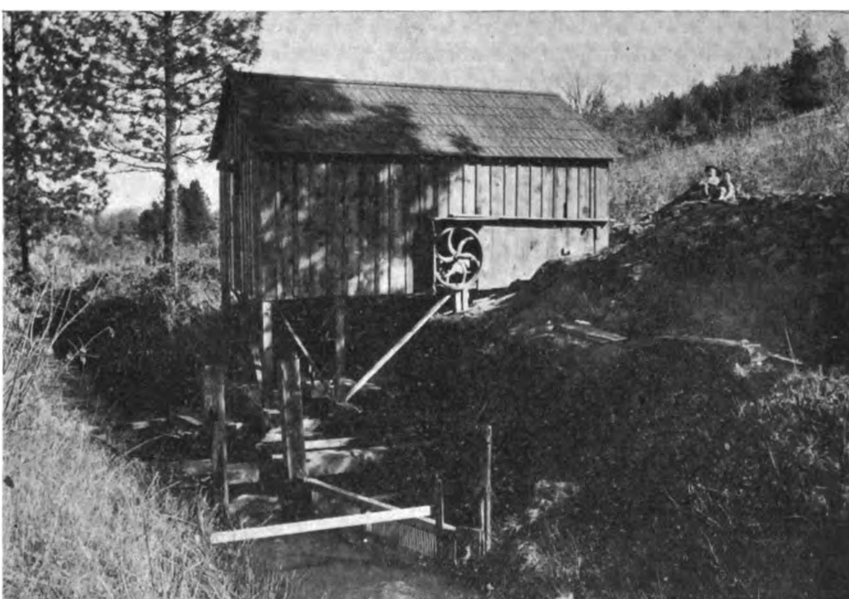

PLATE 1. THE NEW PUMP-HOUSE AND WORKSHOP.

at Ione or at Valley Springs, is of growing importance to the district. Its collections of trees are large and valuable. Its experiments in many cultures adapted to the Sierra foothills have been many and useful. Its possibilities are great, and it will be many years before they can be considered to be exhausted. There has been a marked increase in the horticultural interests of the region during the past five years, and the substation has done much to direct and develop this interest.

The plans arranged for in 1897 and inaugurated by the construction of a new cottage for the foreman at a cost of $900, which was practically completed by the end of 1898, have been carried out in the main as then decided upon. A larger turbine and pump, built by the Sutter Creek foundry, have been completed at a cost of $550 for materials and labor. A new and larger pump-house has been constructed, in which tools can be kept, a work-bench placed, the circular saws used in cutting wood, etc., stored, and work done in rainy weather. The circular saws and the grindstone are run by the turbine. The entire flow of the ditch can now be taken to give power. All that the water system needs to complete it is a large pipe from the pump to the reservoir on the hill. Breaks in the reservoir, due to faulty construction in 1889, have been repaired.

The old tank-house has been removed from the top of the hill and set behind the cottage on a good cement foundation. The ground has been properly terraced and walled wherever necessary near the cottage and the propagating-house.

The economic garden and areas for test plots near the cottage have been materially enlarged, and most of the small fruits placed by the water-ditch.

A separate building has been constructed for an office and seed-house, long necessary here. The cottage contained no room for these purposes, and it has always been desirable to have business headquarters, particularly at a substation which has so many visitors, forty or fifty persons having sometimes come in a single day. The office was built of mountain pine, covered with shakes, and battened, as cheaply as was consistent with durability. The size was 12 by 20 feet, and it was put on a rough stone foundation. The total outlay for labor and materials was less than $200.

Change in Officers.—Mr. J. W. Neal, who had served here as workman in charge and as foreman since June, 1897, was transferred to the substation near Paso Robles (his old home) in the spring of 1901, and Mr. John H. Barber was transferred from Paso Robles to the Foothill substation. The local Patron is still Judge R. C. Rust, whose interest in the welfare of the station remains unflagging.

CLIMATE.

The following brief table shows the temperature and rainfall at the substation from July, 1898, to June, 1901, inclusive:

TEMPERATURE AND RAINFALL AT SIERRA FOOTHILL SUBSTATION FOR THREE SEASONS.

Month.	Max. Temp.	Min. Temp.	Mean Max. Temp.	Mean Min. Temp.	Mean Temp.	Rainfall.
1898—July	104°	50°	94°	64°	79°	trace
August	106	52	90	64	77	0.00
September	98	46	81	57	69	0.40
October	90	38	75	51	63	1.04
November	76	30	59	41	50	2.11
December	62	26	51	35	43	2.70
1899—January	68	26	52	39	45	5.20
February	70	20	56	38	47	0.57
March	72	30	56	38	47	14.60
April	94	30	77	43	60	1.49
May	100	34	74	44	59	1.07
June	96	44	84	58	71	1.00
Season 1898–99	106	20	71	47	59	30.18

TEMPERATURE AND RAINFALL—*Continued.*

Month.	Max. Temp.	Min. Temp.	Mean Max. Temp.	Mean Min. Temp.	Mean Temp.	Rainfall.
1899—July	96°	50°	86°	60°	73°	0.00
August	84	44	78	51	64	0.07
September	90	42	82	59	71	0.00
October	82	30	62	44	53	5.86
November	62	34	55	41	48	5.81
December	58	24	49	35	42	7.45
1900—January	58	28	48	37	42	2.37
February	58	30	48	37	42	2.15
March	64	32	55	41	48	4.37
April	66	32	53	39	46	3.57
May	74	36	64	45	54	1.83
June	82	42	72	52	62	0.06
Season 1899-1900	96	24	63	45	54	33.54
1900—July	94	50	83	60	71	0.00
August	96	48	80	56	68	0.00
September	88	42	77	48	63	0.41
October	80	32	67	45	56	2.74
November	76	34	62	44	53	8.32
December	66	20	50	33	42	2.24
1901—January	62	20	50	33	42	7.13
February	68	22	54	35	45	11.24
March	70	26	60	38	49	2.58
April	72	24	65	39	52	3.82
May	84	32	70	44	57	1.18
June	97	38	82	51	66	0.08
Season 1900-01	97	20	67	44	55	39.74

All these annual rainfalls are below the high average of the seven years before 1897, but are higher than for several previous years. The light and generally sloping and shallow soils of the foothills require a large rainfall to produce fair crops. Only once, in 1897-8, has the total rainfall of the season fallen below 20 inches since the substation was established.

Frosts, and Frostless Locations.—As the above table shows, the minimum in these three years has been 20° Fahr., which occurred in February, 1899, December, 1900, and January, 1901. The lowest recorded temperature at the station since 1889 was 16° Fahr., but this was at the ditch, the lowest point on the tract. The climate is an excellent one, well adapted to olives, figs, and, with care in choosing places in which to plant, to oranges. On the station tract, which varies 168 feet in elevation from the ditch to the top of the highest hill, there is a variation of from 4° to 6° Fahr. The climate varies very much according to elevation, exposure, and air currents, in all the surrounding region. There are many "early spots" being found and utilized by gardeners and fruit-growers, greatly to their profit, in this region, and the importance of location is nowhere more evident than here.

A change of less than 200 feet in the location of the small orange grove at the substation has materially improved the prospects of success with this fruit. Instances of this sort abound in the foothill country. A temperature of 20° Fahr. has not injured the orange trees here.

THE ORCHARD.

The previous report covered crops for the season of 1899. Several important problems are presented in the orchard which only time, patience, and careful observation can work out for this district. Attention will be called to these under the separate subheads.

POME FRUITS.

Apples.—This standard fruit has been given much care here, and the young orchards promise to be very valuable to this region. In 1899, the apple crop was fair, and twenty-four varieties fruited. In 1900, only four varieties fruited, and some of these dropped their fruit. Two varieties, Wolf River on slate soil and McMahon's White on granite soil, both early fall apples here, bore good crops. Clayton, on granite soil, was the only late-keeping variety to mature a crop. Transcendent Crab bore a large crop.

In 1901 the apple crop was chiefly borne by ten varieties, as shown in the following table:

BEST APPLES IN 1901.

Variety.	When Ripe.	Crop, in Pounds.
Hawthornden	Aug. 7	107
Violet	" 9	25
Wealthy	" 10	38
Wolf River	" 20	24
Acme	Sept. 20	20
Lady	" 30	25
Missouri Pippin	Oct. 10	69
Arkansas Black	" 10	26
Ingram	Nov. 15	20
Hyslop Crab	Aug. 14	35

There were many varieties of apples that bore a few pounds of fruit. In most cases the size was small. Gloria Mundi apples averaged a pound each; Wolf River, nine ounces. In quality, Violet, Wolf River, Missouri Pippin, Arkansas Black, and Ingram were good; Acme was distinctly poor.

The problem in the case of apples is evident here. They do not bear as well as they should. At about this elevation, 1,500 to 2,000 feet, there is considerable complaint that apples are shy bearers. The cause does not appear to be lack of moisture as a rule, for the trees make fair growth, and have healthy leaves. Deficient or weak pollination may be the reason in some cases. The dropping of immature fruit offers more difficulty. As the new orchards on different soils and exposures come to bearing age, this trouble can be more carefully investigated. It first appeared to any extent after the dry season of 1897–8, which doubtless had much to do with the present difficulty. It was less in 1899, but greater in 1900 and 1901. Successful apple culture for market in this district depends on conquering this weakness in respect to bearing. Higher up, between 3,500 and 4,000 feet, the apple bears as well as possible.

Pears.—This fruit promises excellent returns in this district, on suitable soil. Old trees on bottom lands near the creeks are of great size, and though unpruned and untilled, often bear large crops. The success of pears, if unirrigated, on the hill slopes depends on soil and culture. The original selection of very poor, thin, slaty soil near the entrance to the substation was a mistake, as none of those trees have thriven. The young pear orchard is on better soil. The pears on the mixed granite and slate soil have done fairly well.

In 1900, eight varieties of pears bore fair crops, namely, Doyenne d'Alençon, Keiffer, P. Barry, Duchesse d'Angoulême, Howell, Josephine de Malines, LeConte, and Mount Vernon. In 1901, the bearing varieties were Bartlett, Columbia, Dr. Reeder, Keiffer, Nouveau Poitou, and P. Barry. A few fruits were borne by twelve other varieties besides these. The quality of the fruit was from fair to excellent. Dr. Reeder, a small, Seckel-like pear, was of the best quality. Bartletts were also first-rate, and Keiffer better than as ordinarily grown in the valleys.

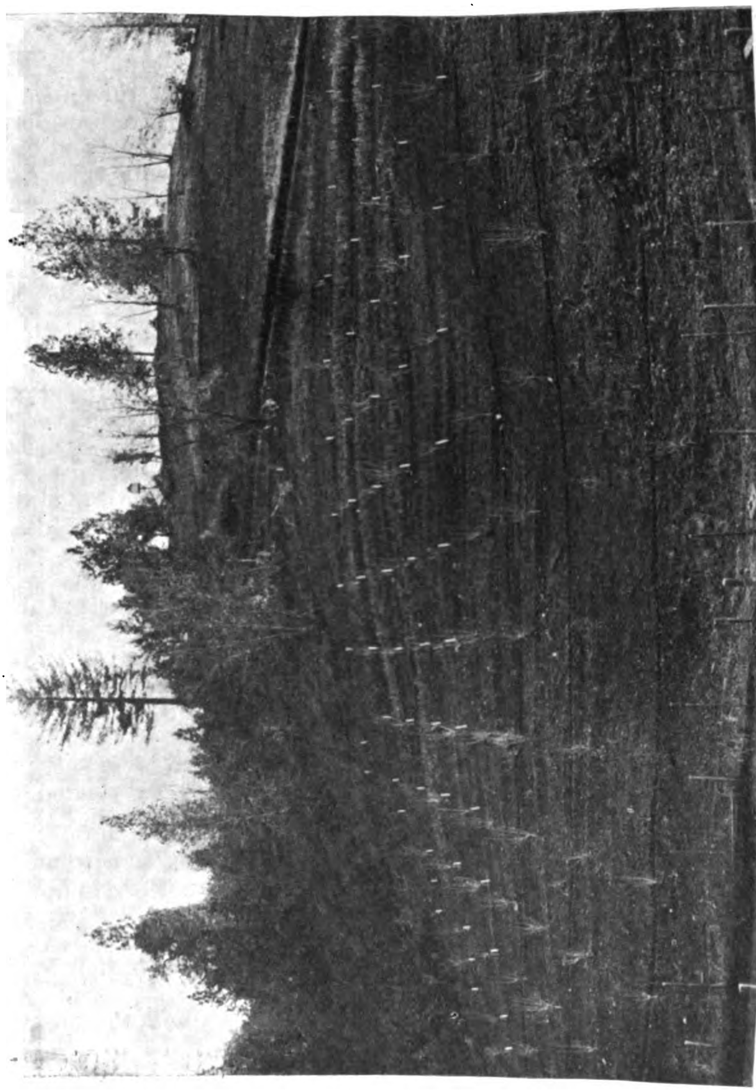

PLATE 2. NEW ORCHARD AT FOOTHILL SUBSTATION.

P. Barry's keeping qualities were notable. Few conclusions respecting the failures of any other varieties can be drawn until the young orchard on better soil is in bearing.

Quinces.—There have been but few reports from this locality upon quinces. One rarely sees quinces in the old gardens, and then finds them utterly neglected and usually pastured down by cattle, as often are apples and pears, into the condition of low, thorny shrubs. The quinces were set in 1889–90, on very light and rocky soil at the lower end of the pear orchard. Here even the olives are stunted. The four varieties—Rea's Mammoth, Angers, Orange, and Chinese—tested, have borne a few fruits for five years past and are improving in health and vigor. In 1901, the largest crop, 24 pounds, was on Rea's Mammoth; Chinese yielded 12 pounds.

Japanese Persimmons.—Previous reports have shown the entire adaptation of this fruit to the slate soil of the region. The trees are in much better and deeper soil than are the first plantings of pears and quinces. They bear very large crops, often all that the trees will carry, and are one of the most uniformly successful fruit crops at the substation. The persimmon attracts much attention, but its uses are less general than in the case of other fruits.

STONE FRUITS.

Almonds.—Previous reports have been decidedly against the success of this crop here, but the season of 1900 showed that when the late spring frosts are absent, the trees, now large and healthy, will give good returns. In those localities where the blossoms can be reasonably expected to escape—and such places exist here and there about this district—the almond can be made a paying crop, as the quality is unsurpassed.

In 1900, the blooming season ranged from January 15th to March 3d; Commercial and Harriott's Seedling being the earliest, and Golden State and Texas Prolific the latest. Late bloomers are preferable here, but Drake's Seedling and the old Languedoc, blooming quite late, are better bearers than the Golden State or Texas Prolific. The earliest to ripen are King's Softshell, Marie Duprey, and Nonpareil (July 28th); Texas Prolific, the latest, ripened August 24th. By ripening is meant the opening of the hull on the trees. The best bearers yielded from 14 to 40 pounds of hulled nuts per tree—the latter crop being that of Drake's Seedling.

In 1901, the spring frosts destroyed all the almond blossoms.

Reviewing five years, Languedoc and Drake's Seedling yielded well in 1897, 1899, and 1900, but were frosted in 1898 and 1901.

Apricots, whose history at the substations resembles somewhat that of the almonds, throve in 1900, when the crop averaged 50 pounds to the tree, large and small. Montgamet, Beauge, and Oullin's Early yielded 90, 100, and 80 pounds, respectively; while Moorpark and De Coulorge yielded 75 pounds each. The largest fruit on the substation is that of Montgamet.

Sardinian began to ripen June 13th; Oullin's, June 20th; Montgamet and Royal, June 25th; Moorpark, June 30th.

The spring frosts of 1901 destroyed the blossoms. As with the almonds, two years out of five the crop has been a failure in this location.

Nectarines.—The crop failed in 1901, owing to frosts; but in 1900 it was fair. The season began August 1st with New White, and ended August 30th with Victoria. The nectarine seems more easily frosted than the peach, and more resembles the apricot in this respect. It is usual to speak of the nectarine as thriving wherever the peach does, but this appears doubtful after the substation experience.

Peaches.—This is everywhere one of the most important of the foothill crops, and there is much land well adapted to its growth. In 1900, the flowering season began from February 25th to March 7th in different varieties, and lasted about ten days. The ripening period, that is, from first ripe to fully ripe, lasts from five to ten days.

The collection of varieties is now so great at the substation that we list only the best—those of high quality and bearing 40 pounds and upward per tree. They are arranged in order of ripening.

BEST PEACHES IN 1900.

Variety.	Ripening Period.	Crop, in Pounds.
Schumaker	June 22 to June 28	45
Governor Garland	" 23 " " 30	45
Ulatis	" 24 " July 3	50
Early Rivers	July 8 " " 15	70
California Cling	Aug. 8 " Aug. 19	40
Newhall	" 11 " " 18	45
Nichol's Orange Cling	" 19 " " 29	40
Newington Cling	" 22 " " 29	75
Columbia	" 29 " Sept. 6	70
Smock's Late Free	Sept. 4 " " 10	60
Beer's Smock	" 5 " " 10	60
Henrietta	" 10 " " 18	75
Salway	" 10 " " 16	100
Wager	" 15 " " 22	60

The peach crop in 1901 was not so heavy as in 1900, for all varieties suffered from frost, but it was a fair one. The early peaches, such as Alexander, Governor Garland, etc., suffered from depredations of thieves, and no exact record was possible. The bloom-period lasted from March 1st to March 10th. Excluding the small early varieties, the following table shows the results:

BEST PEACHES IN 1901.

Variety.	Ripening Period.	Crop, in Pounds.
Large Early York	Aug. 3 to Aug. 9	45
Honey Cling	" 20 " " 24	44
Elberta	" 21 " " 30	52
Newhall	" 26 " " 30	54
Mrs. Brett	" 28 " " 30	97
Muir	" 28 " Sept. 2	41
Morris White	Sept. 2 " " 10	104
Newington Cling	" 7 " " 10	86
Columbia	" 9 " " 12	60
Lemon Free	" 10 " " 20	65
Wilkins' Cling	" 11 " " 15	52
Salway	" 15 " " 27	58
Beer's Smock	" 15 " " 20	113
Crimson Beauty	" 18 " " 27	43
Garey's Hold-on	" 18	119
Henrietta	" 21 " " 28	72
Henrietta No. 2	" 25 " " 30	155
Wager	" 25 " Oct. 2	143

The most reliable "general crop" varieties in 1900 and 1901 were, named in order of ripening, Newhall, Newington Cling, Columbia, Salway, Beer's Smock, Henrietta, and Wager. One may add to this list for very early varieties, Governor Garland, Briggs' May, or Alexander, as preferred; we can also add Honey Cling for quality, and Morris White or Mountain Rose for a good, late white freestone. Henrietta, a fine late cling, is increasingly popular in the foothill region for canning, and Salway and Wager are standard freestones for the same purpose.

Wager, at the Foothill station has always ripened about a month later than Muir, and seems to be a better bearer.

In size, the peaches, with sufficient thinning, are fair, though not large. Henrietta and Wager maintain their normal size better than most other varieties do. A large number of well-known varieties, after years of testing, fail to grow and bear here as well as do the varieties listed and described above. With good cultivation and thinning, the peach trees have been healthy, and have borne high-class fruit for three year's past, without irrigation, on either the slate or the granite soils. About one hundred and fifty varieties of peaches have been tested at this substation since its establishment.

Plums and Prunes.—The culture of plums and prunes in this district presents some especial difficulties. Every class of these fruits has been tested extensively on both slate and granite soils, with varying success, under different methods of pruning and culture, irrigated and unirrigated.

Nevertheless, the value of plums and prunes in this locality remains as yet an undetermined problem. In 1899, 1900, and 1901 about fifty-five varieties were in bearing here; but out of all of these only a few yielded more than 20 pounds per tree.

There are not many European plums which yield well or maintain a healthy growth here. Making every reasonable allowance for differences of soil and location, the Japanese plums, a few of the prunes, and two or three European plums appear to be all that have succeeded at this substation. The Japanese plums bloom so early that they are subject to frost. The few American plums planted here have not yet had thorough trial, but a complete collection of the Americans and crosses of Japanese are indicated by the situation. All the plums do better on slate soil than on the granite.

The following tabulation shows those varieties which came nearest to success here:

BEST PLUMS AND PRUNES IN 1900.

Variety.	Ripening Period.	Crop, in Pounds.
Burbank	July 23 to Aug. 7	150
Botan	Aug. 3 " " 10	45
Chabot	" 17 " " 30	40
Kelsey		30
Pond's Seedling (Hungarian Prune)	Aug. 17 to Aug. 27	25
Victoria	" 8 " " 16	30
Prune d'Agen (French)	" 18 " " 24	25
D'Ente de Puymirol	" 24 " " 31	25

The above list includes four Japanese and two European plums, also two prunes. Some crops were borne by Coe's Golden Drop and Robe de Sergent prunes.

In 1901, the varieties bearing well were as follows:

BEST PLUMS AND PRUNES IN 1901.

Variety.	Ripening Period.	Crop, in Pounds.
Burbank	Aug. 4 to Aug. 10	72
Kelsey	Sept. 1 " Sept. 10	18
Pond's Seedling	Aug. 24 " " 3	50
Victoria	" 27 " " 4	40
Columbia	" 21 " " 1	60
McLaughlin	" 2 " Aug. 12	25
Grand Duke	Sept. 5 " Sept. 15	40
Prince of Wales	Aug. 12 " Aug. 21	25
Prune d'Agen	Sept. 15 " " 25	63

In both these years, as in 1899, Burbank, Kelsey, Pond's Seedling, Victoria, and Prune d'Agen were among the list and were of very fine quality. The breakdown of European varieties here occurred between 1893 and 1897, during which years failures in bearing were general in plums of this class. Prunes also did poorly, but are now thriving much better than before. The plums and prunes present one of the most interesting of the many practical problems connected with this substation. Old and healthy plum trees are extremely scarce in the pioneer gardens of this region. Some good Petite d'Agen prune orchards are found in the neighborhood.

Cherries.—Previous reports on the gum disease and the failure of cherry trees at this altitude are still in the main true, but the three years, 1899–1901, show some improvement, as there has been more rainfall and less frost and the trees are stronger. The season in 1900 was from May 1st to June 15th for first ripening; in 1901, it was from May 5th to June 15th. Belle d'Orleans ripened both years long before Early Purple Guigne, a curious illustration of the vagaries of climate. Royal Ann was one of the latest. The best bearers in 1900 in red soil were Early Purple Guigne, 60 pounds; Bauman's May, 75 pounds; Coe's Transparent, 60 pounds; Napoleon Bigarreau, 65 pounds; and Belle d'Orleans, 40 pounds.

In 1901 the crop was smaller than in 1900, owing to late frosts. Many new varieties have not yet come into bearing. Some of them are entirely free from gum disease. The cherry is not largely planted in this region. A little lower down it does very well. At Sutter Creek, cherries ripen extremely early, and would probably command a good market on that account.

SEMI-TROPIC FRUITS.

The Fig.—There is no more promising fruit here than the fig. The avenue planted around Reservoir Hill when the station was established has thriven, and has very seldom suffered from frost or drought. In some important particulars this substation is the best one in California, and probably in the United States, for tests of figs. At Tulare many sorts are often frosted; Paso Robles is altogether too cold for the fig; at Pomona a great many varieties are subject to "fig sour."

Previous reports have listed the varieties being tested at this substation. In the spring of 1901 a new collection, including varieties of Capri and Smyrna, donated by Mr. George Roeding of Fresno, was planted here, and other new varieties are in the nursery, so that with the large Capri fig of the original importation, the breeding of the fig wasp can soon be undertaken.

In 1900, Black Marseilles, Brown Ischia, Gros Gris Bifere, and Monaca Bianca bore an early crop. Main, or summer, crops were borne by Black Marseilles, De Constantine, Dorée Narbus, Monaca Bianca, Agen, and White Adriatic. The last named, until the Smyrna types can be fructified, remains the best drying fig here.

In 1901, Breba, which often needs fertilization, bore an early crop; so did Petrovaca and Pastiliere. Good summer or main crops were borne by Abondance Précoce, Agen, Black Marseilles, Bourjassotte Grise, Cernica, Col di Signora Nero, Dalmatino, De Constantine, Dorée Narbus, Early Violet, Kargigna, Monaca Bianca, Pastiliere, Ronde Noire, White

Adriatic, White Genoa, White Ischia, and White Marseilles. These varieties bearing in 1900 and 1901 have generally proved the most reliable here.

Olives.—The crop of 1900 was the best ever known at the substation, and more varieties bore than in any previous year. This location is an excellent one for the olive; the trees are healthier and bear better than at any other substation. The avenues here, begun in 1889, and since extended, are well worth the study of every land-owner in the Sierra foothill region. Notes upon the frost-endurance of olives here and elsewhere appear in a separate article.

In 1900 the olive trees blossomed, according to variety, between May 17th and June 5th. The following table shows results where crop was 10 pounds or more:

THE OLIVES IN 1900.

Variety.	Soil.	Oil in Fruit.	Crop, in Pounds.
Amellau Amygdalina	Granite	Nov. 14	30
Atrorubens	Slate	" 20	45
Atroviolacea No. 1	Slate	" 5	85
Atroviolacea No. 2	Slate	" 5	70
Atroviolacea No. 3	Granite	" 6	27
Caillon Rubra	Granite	" 5	18
Columbella	Red	....	65
Corregiolo	Granite	Nov. 17	26
Lavagnino	Red	" 6	35
Leccino	Granite	" 4	5
Lucques	Red	" 15	70
Macrocarpa	Red	" 4	55
Manzanillo	Red	" 7	50
Manzanillo No. 2	Red	" 7	35
Manzanillo No. 3	Granite	" 9	11
Mission	Red	....	heavy
Mission No. 2	Granite	Nov. 10	10
Mission No. 3	Granite	" 15	11
Nevadillo Blanco	Red	" 7	30
Nevadillo Blanco	Granite	" 6	11
Nigerina	Red	" 8	15
Nigerina No. 2	Granite	" 7	35
Oblonga	Red	" 4	27
Pendulina	Granite	" 5	23
Polymorpha	Red	" 2	11
Polymorpha No. 2	Granite	" 3	23
Præcox	Red	" 1	28
Razzo	Red	" 6	16
Regalis	Red	....	55
Regalis No. 2	Granite	Nov. 10	11
Rufa	Red	" 3	40
Salonica	Red	....	80
Uvaria	Red	Nov. 1	45
Redding Picholine		" 4	60
Redding Picholine	Granite	" 6	45

Some of these yields are remarkable, such as that of Atroviolacea, Columbella, and Salonica. The yields of 10 and 11 pounds per tree come, in most cases, from younger trees than those of the main avenue.

Olives in 1901.—The bloom period of the olives in 1901 was between May 21st and June 10th. The hot dry winds of the late spring and early summer injured the blossoms, or the yield would have been, as a whole, fully equal to that of 1900. The pickling varieties which best withstood the winds were Macrocarpa and Mission No. 1 on the slate soil, and Polyantha on the granite. (There is no bearing Macrocarpa on the granite; the Missions usually do best on the slate soils.) The best oil-producing varieties were, on the slate soil, Atroviolacea, Uvaria, and Lucques; while Pendulina and Caillon Rubra did best on the granite.

The crops yielded by the fifteen best bearing trees were as follows (in pounds): Mission No. 1, 78; Macrocarpa, 69; Atroviolacea, 57; Uvaria, 56; Redding Picholine, 46; Lucques, 38; Atrorubens, 36; Manzanillo, 31½; Polymorpha, 28; Præcox, 24; Razzo, 22; Oblonga and Caillon Rubra, 20 each; Rufa and Regalis, 18 each.

The foreman makes the just observation that Manzanillo "appears to be the best all-round olive here," having a fair crop every year, but doing best on the slate soil, as would be expected. Uvaria and Atroviolacea are to be recommended among the oil varieties, and Manzanillo and Mission among the larger sorts, used for pickling as well as for oil. The substation has for several years recommended these four varieties to planters here, and a great many trees have been set out, chiefly by the thrifty Italian land-owners.

Redding Picholine, besides being small and poor, bears very unevenly; some trees have no crop at all, while others are overloaded; it is not to be recommended. Mission No. 1 and No. 2, sent to the substation in 1889 by the late Mr. Klee, then Inspector, differ little from each other. Though one was thought to be much earlier in point of ripening, it has practically lost this advantage as the tree became older.

The manufacture of olive oil on a small scale has been carried on for two seasons, the machinery required being paid for by the surplus oil produced, and excellent samples of leading sorts and of blends being sent to the Central station and placed on exhibition.

Walnuts.—The quality of the walnuts grown here is notably high. The size of the nuts is not large. The trees do not always bear well, and so the exact place of this valuable crop in foothill orchards must be determined by further observations. Bijou bore 40 pounds in 1900 and 24 pounds in 1901. Santa Barbara Softshell yielded 20 pounds in 1900 and 48 pounds in 1901; Dwarf Prolific bore 19 pounds in 1900 and 34 pounds in 1901. Chaberte and Serotina are practically failures as regards bearing. Franquette, Vourey, and some other grafted trees of the best French varieties do not yet bear well.

The walnut, like the chestnut, merits long and careful experiments here, as both crops promise to be valuable. Though often shy bearers, so much depends upon the variety, location, and treatment, that the culture of both walnuts and chestnuts is difficult. The shrewd and careful Italians of Amador and adjacent counties who have had much experience in vineyards, are taking up olive culture and are showing interest in walnuts and chestnuts, as they also will in figs; so that a distinctive semi-tropic horticulture is being slowly developed here.

SMALL FRUITS.

The collections of small fruits here are large, and plants have been widely distributed in the district. Blackberries, raspberries, gooseberries, currants, strawberries, and other small fruits have received thorough tests. All require irrigation here. The common local method of applying water is wasteful, and false in principle, as it is simply run in shallow, open furrows at short intervals and no cultivation follows. Much less water, at longer intervals, with thorough subsequent culture, produces better results at less cost. Strawberries, raspberries, and blackberries are excellent here and easily produced. Currants suffer from sunburn, needing protection. Some gooseberries, notably the Oregon Champion, have done very well.

Blackberries.—Erie begins to blossom here about the end of April, and continues until early in June, grows well and bears heavily, ripening fruit from June 20th through July. Crandall has grown well, but is not, so far, much of a bearer. Ole Bull began to blossom about the middle of April, ripened from June 13th to July 18th (in 1900), crop medium, berries small. Early Harvest ripened fruit June 6th—not a striking growth. Kittatinny began to ripen June 18th, continuing to August; berries large, a good grower. Minniwasky, a berry received from El Dorado County under this name, ripened from June 21st to August, and yielded well. Cosumnes, a native Californian blackberry from the Sacramento Valley and a valuable stock for further crosses, began to bloom early in April, ripening fruit from June 16th to July 25th; quality high.

The Lucretia dewberry is excellent here. It requires a low trellis, either flat or upright. Ripened from June 7th until nearly August, 1900. All of the dewberries suit the district, and are a useful, hardy fruit, closely allied to the blackberry.

Raspberries.—Hurlbert usually blooms early in May, and bears well. Mammoth Cluster has bloomed April 20th, and ripened fruit June 11th. Golden Queen, French, Hudson River, Surprise, Marlboro, and Gladstone bloom about the same time, and begin to ripen within two or three days of the same date—about June 10th. All are excellent in quality. Many other sorts have been tested, but none are better than these.

Other Berries.—The Loganberry blooms here about the middle of April, and begins to ripen about June 1st. It is a very heavy bearer when trellised, and should be generally planted in the foothills.

The "Japanese Wineberry" is a strong grower and heavy bearer, but has no practical value.

The "Coralberry," "Muskberry," and "Mayberry," received from S. L. Watkins of Grizzly Flat, El Dorado County, have blossomed, but set few and worthless fruits. Like the "Wineberry," they should be discarded from the list.

THE VINEYARD.

An important part of the substation is the large vineyard, on both slate and granite soils, containing one hundred and fifty varieties of table and wine grapes. The local demand for cuttings of wine grapes is at present confined to those varieties which bear large crops. A good deal of wine is made for the local market, but very little finds its way elsewhere, and quantity is the main thing with all growers in this region. As transportation facilities improve, the making of better wines will attract more attention; and the fine collection of varieties at the substation will be more generally drawn upon.

The bearing quality of some varieties has improved with age and with changes in method of pruning. The foreman, Mr. J. H. Barber, furnishes the following interesting synopsis of his observations here, noting in parentheses the method of pruning which is best:

Varieties for Dry Red Wine.—Aramon (short pruning), Bastardo (half-long), Carignane (short), Grenache (short), Mataro (short), Mondeuse (half-long), Mourastel (short), Petit Bouschet (short), Tinta Val de Peñas (half-long). Preference for quality combined with bearing capacity should be given to Aramon, Carignane, Mataro, and Tinta Val de Peñas. Aramon is also a fine table grape for local use, and Tinta Val de Peñas a very acceptable one.

Varieties for Dry White Wine.—Burger (short pruning), Sauvignon Vert (short), Semillon (long).

Varieties for Sweet Wines.—Port type: Tinta amarella (half-long).

Sherry type: Palomino, or Golden Chasselas (short or half-long), West's White Prolific (short), Boal de Madeira (half-long), Mantuo de Pilas (short), Mourisco branco (short). Preference for quality is given to a mixture of two thirds Palomino and one third Boal; these varieties ripen at the same time. Palomino is a very acceptable table grape, as are also Mantuo de Pilas, Mourisco branco, and Tinta Amarella.

Cuttings of table grapes are in great demand, and the range of varieties wanted is much wider than in the case of wine grapes. A succession is desired, and quality counts for much. The substation, modifying, as experience dictates, previous lists, now recommends the following table grapes:

White.—Luglienga (July grape), Chasselas de Fontainebleau (sweetwater), Small Muscatel (Frontignan), Palomino (Golden Chasselas), Muscat of Alexandria, Huasco (which some prefer to Muscat), Mantuo de Pilas, White Tokay, Peruno, Pizzutello di Roma, Mourisco branco, Napoleon, Verdal, and Almeria.

Red.—Barbarossa, Flame Tokay, and Zabalkanski.

Black.—Tinta Val de Peñas, Cinsaut, Aramon, California Black Malvoisie, Tinta Amarella, Moscatello fino (Black Muscatel, a light bearer but of finest quality), Gros Colman (here of better quality than in the valley), Black Morocco, and Emperor.

The above list covers a season here of from July 25th until rains and frosts destroy the fruit, usually in November. Emperor and Almeria, picked and hung in a cool dry place, will keep until nearly Christmas.

The foreman further cuts down this list of table grapes, for home vineyards, as follows: "A good selection for the home vineyard would be the following: Luglienga, Aramon or Cinsaut, Tinta Val de Peñas, Palomino, Huasco, Mantuo de Pilas, Gros Colman, Pizzutello di Roma, Flame Tokay or Zabalkanski, Verdal. Of these, Luglienga, Pizzutello, and Zabalkanski should have long pruning; Tinta Val de Peñas and Palomino, short or half-long; the remainder, short. Luglienga and Pizzutello are good vines for arbors or trellises; in that case Pizzutello should be pruned to short spurs on long arms, as is the Mission when grown on an arbor."

There is as yet no demand for "shipping grapes" in this district, but when it comes, Flame Tokay will not be useful, as it bears poorly. Emperor, Mourisco branco, and Almeria promise better. There is only a small local demand for raisin grapes here. The quality is excellent, and the varieties planted are Muscat of Alexandria, Huasco, Thompson's Seedless, and Sultana. Muscats are to be pruned short; the seedless kinds are properly pruned long or half-long, according to soil.

TEST PLOTS AND SMALL CULTURES.

At no substation has a larger range of cultures received trial than at Amador. This was because the district was entirely new, and no farmers in the region were making tests of anything, but continuing to plant only a few staple crops, and a few varieties of these. Since 1889, therefore, the small cultures of the substation have been of much local interest. The following notes cover only the more striking results of this long-continued work, much of which is complete:

Saltbushes.—The experience with *Atriplex semibaccata* has now lasted four years. It has been planted in the field, on both red and granite soils, irrigated and non-irrigated, cultivated and not cultivated. If protected from the hares and squirrels, which are numerous and very fond of this plant, it grows, but no better than some other forage plants. It does not hold its own well on the hillsides with other plants, but its habit of early winter growth gives it some value here. It has done quite well on granite soil, plants here covering a circle of two feet in diameter. The hairy vetch seems much better adapted to this region, and is more easily naturalized in the pastures. Sheep, and as noted, wild animals, are extremely fond of the saltbush—more so than in valley districts, and it is worth growing on a small scale.

Atriplex leptocarpa (a trailing species), sown March 19, 1900, grew fifteen to twenty inches from the crown that season. It does not naturalize at all here.

Rhagodia spinescens inermis grows very large, three to four feet high, furnishes much fodder, and if started in boxes and transplanted to the rough hillsides, would afford much forage for animals. Its power of naturalization has yet to be determined, but plants do not seem strong.

Grasses and Clovers.—*Bromus inermis* (Hungarian brome-grass) has been thoroughly tested. It keeps green nearly all summer, without irrigation; should be sown early—say in November. Unless irrigated, the growth on either slate or granite soil is small—perhaps three or four inches in height. In September the top dies down, unless given water. A very little irrigation greatly improves it and lengthens its season. This grass appears to naturalize itself in favorable cases, and should be extensively sown.

A collection of ten varieties of evergreen and perennial rye-grasses from Sutton & Co., England, were sown in March, 1900. They grew from ten to twenty inches high, and were cut three and four times in the season. They were irrigated, and showed great value for small fields under ditch. Grown without irrigation, these grasses died out in summer. One of the best was the "Selected Perennial." When irrigated on red soil, Sutton's Perennial Red Clover grew to fourteen inches in height between March 1st and June 1st, 1900. It was thereafter cut three times. Red clover is a promising crop in this region, and sometimes grows twenty inches high by June 15th. Sutton's Giant Hybrid Clover, Perennial White Clover, and Yellow Trefoil were also grown, but only the first of them seems worthy of further trial.

Common White Clover (*Trifolium repens*), sown November 28, 1899, on granite soil, did poorly; on red soil with irrigation it did well.

Alsike, or Swedish Clover (*Trifolium hybridum*), is a very promising clover for this region. With irrigation, it can be cut three times in a season, and has kept green until midsummer on granite soil without irrigation.

Egyptian Clover (*Trifolium Alexandrinum*) is a very promising crop. Seed sown November 23, 1899, on granite soil, without irrigation, grew sixteen and eighteen inches high and died down. An irrigated plot continued green all summer, started from the roots in early winter of 1901, and grew until midsummer. Unless irrigated, this clover must be resown every year; if irrigated, it will furnish very early pasturage.

The Common Snail Clover (*Trifolium turbinatum*) has been grown here for ten years. It covers the ground early, and if irrigated can be cut three times. Without irrigation, it begins to die down by the middle of June or first of July.

Beets and Other Field Roots.—There have been careful tests of all the leading field root crops, both with and without water, and on both granite and slate soils. These tests included carrots, parsnips, beets, turnips, etc., from the lists of Vilmorin, Sutton, Thorburn, Burpee, and other seedsmen. Early sowing is in all cases essential. With good cultivation, small root crops can be had on slate soil without irrigation. With irrigation, the crops are strikingly large. Beets, parsnips, and carrots do very well; turnips do poorly and have no place in the foothill farmer's rotation.

The great value of root crops for the farmers in this region deserves special emphasis. In the case of mangels from the best obtainable seed, Yellow Globe, with irrigation, yields at the rate of 30 tons to the acre; Mammoth Long Red at the rate of 43½ tons; Champion Yellow Globe at the rate of 72½ tons, and Red Globe at the rate of 54 tons. Some twenty sorts have received trial, and none have yielded less than 30 tons per acre. The Improved Kleinwanzleben deserves general use in this region. Irrigated once, and allowed to grow large for feeding, its sugar percentage would not be more than 8 or 9, but that is considerably more than in the case of Danish or of the various mangels.

Field parsnips have yielded at the rate of 40 tons per acre; White Belgian carrots did no better. There is need of more experiments with root crops in regard to best amount of seed to drill per acre, and many details; experiments until now have been with small plots. No fertilizers have been used.

Jersey Kale has been sown here three times. It grows very well on both granite and slate soils, and needs little irrigation, but requires protection from wild animals. A useful garden crop and new to this district.

Tagasaste has grown fairly well here, but failed on the hilltop when planted out to take care of itself; hence, it is useless here.

New Siberian Golden Millet has been grown twice here. Sown in November, it started badly; sown in March on red soil, it headed out May 30th when four feet high. An excellent hay crop. Seed distributed one season. Not equal to the broomcorn millets which were sent out by the Department of Agriculture, as elsewhere noted.

Buckwheats.—Six varieties from Berkeley, grown in plots in 1896. All kinds throve, especially the California and the Japanese. Sown again in 1899, the seed did not germinate.

Flax.—A collection of flaxes has been grown here, attracting much attention. The varieties were California, Royal (from Germany), White Flowering (from France), Belgian Improved, Russian Pskoff, Pure Riga, White Dutch, and Yellow Seeded. Sown November 23, 1899, these varieties began to bloom April 18th to 23d. The height of Royal was 30 to 36 inches; of Belgian, 36 to 42 inches; and few plants of any variety were below 25 inches. The fiber was excellent, and the seeds plump and bright.

Lupins.—Experiments with lupins for green-manuring have been followed for several years at this substation. In some seasons the results have been very promising, but in others less so. On the whole, the prospects of practical results valuable to the farmers of this region are improving.

European Yellow Lupin, sown November 6, 1899, in eighteen-inch drills, seed dropped ten inches in the rows, soil mixed slate and granite, made plants six inches high by March 15, 1900. Did not cover the ground. Sowed too thinly, but previous thick sowing had made the plants slender.

Large Blue Lupin, under similar conditions, grew sixteen inches high, and was in full bloom March 16th, but the foliage was light and tubercles scant.

Large White Lupin reached a height of seventeen inches, with heavy foliage and wide spread of branches, by March 15th. The ground was fairly well covered. This lupin was in full flower by March 12th.

The Large Rose Lupin grew taller, but more slender. The common European Blue did poorly. *Lupinus tricolor* was a failure, and *L. angustifolius* little better.

In 1900–1901, the lupins suffered much from squirrels and hares; but being sown early and the season being mild, they grew larger than in the previous year, affording good covering to the ground and making a profitable fertilizer. The large lupin plots have been fenced with wire, which measurably keeps out depredating animals, and the area devoted to this culture has been extended on poor soil which needs fertilization. The Large European White Lupin appears to be the best variety to plant in this locality.

SEEDS FROM THE DEPARTMENT OF AGRICULTURE.

The following notes are chiefly upon plants the seeds of which came under numbers from the Section of Seed and Plant Introduction of the Department of Agriculture. Some notes on the same species otherwise obtained are included.

Muskmelons.—Nos. 1117, 1118, 1140, 1142, 1144, 1145, 1147, 1148, and 1208 were planted in the spring of 1900 on red soil. Growth was not strong, and all varieties set poorly. No. 1118 was a delicious, green-fleshed melon, weighing 4½ pounds to the average fruit. The late or winter varieties did not seem desirable for home market.

In 1899 a large collection of Turkestan muskmelons from Bokhara and Amu Daria were grown (Nos. 124, 125, 126, 127, 129, 130, 132, 133, 139, 141, 145, and others). The quality of these melons was poor and none of the vines bore well. Seeds of a few of the more promising were distributed for further trial elsewhere.

It appears necessary to irrigate all melons once or twice here, to produce good crops on the hill-slopes. Melons do well on some of the bottom lands without any irrigation.

Stock-melons.—The Khama stock-melon from South Africa, so successful at the substation in southern California, did but poorly here. The Kansas stock-melon also failed to bear well. This crop is not adapted to the district.

Watermelons.—Always of very fair quality here; the crops on this soil are light, and the fruit small. The leading varieties known have been planted.

Vetches.—Many kinds of vetches have been tested here, in past seasons, some from the Department of Agriculture, others directly imported from Vilmorin and others. *Vicia ervillia*, the black bitter vetch from France (No. 1452), sown December 3, 1900, grew from twenty to twenty-five inches in length of branches, and blossomed throughout May. Considered a valuable vetch in Algeria. Yield not equal to that of *V. sativa* here.

The Kidney Vetch (*Anthyllis vulneraria*) (No. 1503 of the Inventory) was grown here in 1896, when this "yellow sand clover" did fairly well on granite soil, making sparse foliage. Again sown in November, 1899, on both granite and slate soils, it did very poorly, growth stopping when hot weather came.

Vicia sativa, or common Spring Vetch (Nos. 1504 and 1505 of the Inventory), and also *V. sativa cordata*, have been grown, the former for several seasons. They require sowing as early in winter as possible, and will then make a heavy spring growth on both granite and slate soils. They stand the hot weather quite well. Department seed of *V. sativa cordata*, sown November 23, 1899, began to bloom May 17th on the granite soil and June 6th on the slate. *V. sativa*, sown on same day, bloomed May 20th on the granite and June 13th on the slate soil. Its yield was heavy, and it can be strongly recommended to farmers as an excellent forage plant here. *V. sativa cordata* did better than the ordinary form.

No. 1507, the white variety of *Vicia sativa*, did but poorly when compared with *V. cordata*, as reference to the table will show. An irrigated plot on red soil grew 4 feet high, blossomed throughout June, and exemplified the profit of using water where available.

Vicia macrocarpa (No. 1508), a massive, large-leaved species, did very well on two trials, and is worthy of further planting; as also is *Vicia narbonensis* (No. 1509), which on slate soil yielded heavily and is one of the best annual vetches tested at this substation. The main sowings of *V. narbonensis* were November 6 and November 23, 1899. It failed on the granite soil.

Another promising annual vetch, but only for the slate soil, is *V. fulgens* (No. 1514), from Algeria, a showy and useful species. Both this and *V. narbonensis* reached a height of 3½ to 4 feet on the slate soil. The bloom period of *V. fulgens* has begun as early as May 17th and as late as June 13th. It appears especially well adapted to these hillside pastures, and is highly recommended by Dr. Trabut of Algiers.

The "Narrow-leaved Vetch" (*V. angustifolia*) (No. 1511), sown in November, blossomed May 26th on the granite and June 15th on the slate soil. The yield was not large.

Vicia atropurpurea, sent from Berkeley in 1899, sown November 23d, blossomed May 22d on the granite and June 15th on the slate soil. It grew 2 and 2½ feet high, and yielded a medium crop. Under similar conditions, *Vicia peregrina* did not do so well. *Vicia Bythinica* proved a promising species on both soils.

But the most useful species tested at the substation seems to be the old *V. villosa*, or Hairy Vetch, perhaps because its culture has been carried on since 1890 and it is now somewhat naturalized on the hill-sides. Seed has been sent from Berkeley several times, and has also been gathered at the substation. The last sowings, November, 1899, were on both soils. On the granite, this vetch blossomed May 10th; on the slate, June 1st. The growth was "thick-matted" and 6 feet from the crown on either side. A plot sown broadcast with Russian rye blossomed June 4th (poor granite soil). The rye germinated badly; the vetch yielded better than any other crop ever put on this soil. Hairy Vetch is extremely well adapted to this region, can be naturalized in pastures better, it would seem, than the Australian saltbush, affords more fodder, and justifies much more extensive trials.

Hairy Vetch, sown broadcast November 7, 1900, on mixed slate and granite soil (but light and poor), came up thickly, made 2 to 4 feet growth from the crowns, and blossomed in May. Used as pasture on pure granite soil, it did nearly as well. Sown on similar soil March 2, 1901, it grew 10 feet from the crowns, and bloomed in June. Sown too late for best results.

The following synopsis shows the yield of the best of these different vetches in 1900:

Name.	In Full Bloom.	Yield per Acre, (Green), In Pounds.
Vicia peregrina	June 4	14,620
Vicia atropurpurea	" 4	17,240
Vicia fulgens	" 4	18,150
Vicia Bythinica	" 5	19,057
Vicia narbonensis	May 25	25,400
Vicia sativa	June 4	25,410
Vicia sativa cordata	" 4	30,855
Vicia villosa	" 4	32,670

In previous years (1895 and 1896), small plots of *Vicia villosa* have yielded on red soil, unfertilized and unirrigated, at the rate of 20 tons of green fodder per acre. The experiments thus far indicate that *V. sativa*, *V. sativa cordata*, *V. narbonensis*, and *V. villosa* lead all others in practical value here, and of these *V. villosa* seems best adapted to the district.

Lentils.—No. 1346 (a Russian variety), No. 1466 (the small queen or March lentil), No. 1467 (the red winter lentil), and No. 1483 (the one-flowered *V. monantha*) have been grown here. In addition, the "Big Hiller Lentil," from Russia, and a collection of lentils from Vilmorin, were planted. All of these received several tests on both soils. Lentils sown early are well adapted to the red soils of this district, though as yet but slightly known. Sown early in November, they bloom early in May. Nos. 1466 and 1467 grew 1 foot high and spread 2½ feet in the rows. Crop excellent. No irrigation is needed. The granite soil produces little.

One plot of No. 1483, the one-flowered lentil, sown December 3, 1900, made a growth of 2½ to 3 feet in length of vines, blooming May 15th. Crop excellent.

Turkestan Alfalfa.—The Department of Agriculture sent, in the fall of 1898, and again in 1899, Nos. 1150, 1151, 1159, and 1169 of the alfalfa (*Medicago sativa*) known as *turkestanica*. As at both Paso Robles and Tulare stations, this alfalfa seems hardier and more drought-resistant than the common variety, but yields no better. There is no appreciable difference among these lots of Turkestan alfalfa. None of them have seeded well.

At Amador substation the plot suffered much from squirrels and hares, which climbed a three-foot wire netting. Close measurements of results are impossible here until the entire station tract southwest of the ditch is fenced against these animals.

Turkestan alfalfa blossoms here about May 15th, when it is 14 to 15 inches high, without irrigation, on mixed soil; and when 18 to 20 inches high on the slate soil. One irrigated plot reached, by June 15th, a height of about 26 inches, and, being protected from animals, was cut three times (season of 1900). The above plots were sown in November. Plots sown in March did not bloom until June 16th, but made three cuttings and were nearly as large as that sown in November.

This lucerne from central Asia possesses a large root system. Its leaves are more pubescent, and in the dry season they turn more edgewise toward the sun. Hence the plant exhales less moisture. Under irrigation, these features are less marked.

Cuzco Maize.—The large-seeded, tall *Zea mays* from Bolivia (Nos. 758 and 759) failed to mature here. It requires irrigation. The kernels are hardly half-ripe when the frost comes.

Velvet Bean.—The "velvet bean" (*Mucuna utilis*) received from Florida was grown in 1898. It made a very poor start, and did poorly, needing more moisture. Bears no comparison with the vetches.

Safflower.—The well-known safflower, *Carthamnus tinctorius* (No. 1345 of the Inventory), was grown in this region years ago, and occasionally appears in old gardens. Since tested on the substation, it proves very easy of growth on both soils, very drought-enduring. Does not compare with the Russian sunflowers as a yielder of seeds for oil or chicken feed. Sunflowers are healthy and of the easiest culture here.

Artichokes.—Several collections of *Cynara scolymus*, including Nos. 1364, 1365, 1366, and 1367 of the Inventory, have been grown here, with irrigation, and give excellent results. Degenerated artichokes run wild on the hill-slopes, are sometimes found in this region, but "go to seed" in early summer. Offshoots have been locally distributed.

Cotton.—The Peruvian cotton (No. 1363) proved too late a species to mature here. Collections of cottons from Georgia and elsewhere have been grown on several occasions, and the ordinary upland varieties mature well here, are healthy, and make a medium growth without irrigation, on the red soils; on the poorer granite soils they have failed entirely.

March Rape.—This quick-growing form of the common field rape (*Brassica napus*) (No. 1449 of the Inventory) has been one of the most promising plants for quick-growing forage ever tested on light granite soils. It must be sown early in November, or with the first rains, and will grow all winter. This and the Essex Rape are recommended by the station for more general trial in the Sierra foothills, but the March Rape does better than the Essex. It should be sown in drills, on well-prepared soil, at the rate of two pounds per acre, or broadcast at the rate of five pounds. If the land is very poor so that plants do not branch much, it should be sown even more thickly than this. But on the granite soil at the substation, rape has covered the surface, growing three to four feet high, and yielding at the rate of 32 tons of green fodder per acre. As this is land which will hardly produce half a ton of cured barley hay per acre, the value of the crop is evident. March Rape sown on slate soil yielded at the rate of 47 tons of green forage per acre.

If the winter is cold and wet, rape can be drilled on raised furrows, to allow an earlier start. It is valueless here for summer pasture. The growth of our wild mustard and turnip, which start with the first rains, afford a clue to the proper place of rape on foothill farms.

Sulla.—This perennial legume (*Hedysarum coronarium*) has been tested on both soils since 1891. It stands the climate well, but fails on the granite. On the slate soil it grows three feet high. It shows no inclination to naturalize itself on the hillsides, and often needs some irrigation to carry it through the summer.

Garbanzo.—This, the "Pois chiche" of France, corrupted to the "chick pea" of catalogues, and called by some seedsmen "Idaho pea," is well known in California as "Garbanzo," a common table vegetable. Seed was received under the Inventory numbers 2139 and 2376. Sown December 3d on slate soil, it was eighteen inches high June 15th, and did fairly well without irrigation. If watered, it makes a large growth. The late spring sowing recommended elsewhere is not satisfactory here.

Broad Beans.—All the leading varieties of *Vicia faba* have been tested here. A collection from Sutton & Co., and one from Vilmorin were planted, also Nos. 2064, 2065, 2066, and 2375 of the Inventory. The best of the last-named in point of growth was No. 2375, the "Windsor." All these English or broad beans are hardy here, require sowing with the first rains on slate soil, and yield heavily without irrigation. A profitable crop for the farmers. The table use of this bean is only to be seen among Portuguese families.

Field and Other Peas.—Victoria field pea (No. 1173), from Moscow, originally an English variety, was tested in 1899 and 1900. Sown in November, it grows but slowly and not large. *Lathyrus sativus* (No. 1175), cultivated in the Volga River provinces, is a bitter vetch used "in moderation with coarse fodder" (Inventory No. 2, U. S. Div. of Botany). Too freely used it is injurious. It grew but poorly at the substation. Nos. 2120 and 2121 were edible-pod peas of good quality for the table. The "gray field peas" (*Pisum arvense*) (Nos. 1485, 1486, and 1487), sown in drills, made fair growth, but were not equal to the best vetches.

GLUTEN WHEATS.

Experiments with the so-called "gluten wheats" have continued for two years here, as at other substations. The following notes show yield on small, drilled plots, in the season of 1900–1901:

Theiss (No. 3823), from the original stock, sown November 30th on granite soil, grew three feet high, and was cut July 8, 1901. It only yielded at the rate of 198 pounds of grain per acre. Seed of this original stock, harvested at Tulare substation in 1900, sown on this soil, yielded in 1901 at the rate of 340 pounds per acre. Seed harvested in 1900 at Amador, yielded in 1901 at the rate of 11,041 pounds of hay per acre. This plot was on slate soil, and fertilized with nitrate. Unfertilized, it yielded at the rate of 10,729 pounds per acre. The light granite soil hardly makes any grain here, and only a very small crop of hay, even in years of greatest rainfall, unless fertilized.

Fultz wheat, original stock (No. 5493), sown on granite soil November 30, 1900, yielded at the rate of 214 pounds per acre. One third of both the Fultz and the Dawson were destroyed by squirrels.

As these hard wheats are grown at this substation in successive generations from the original, the kernels become more puffed up, lighter in color, and show an increasing layer of starch. The plants spread less on the surface when small, and the yield of grain is greater. The original wheat seems to hold its own less here than at Tulare.

SOUTHERN COAST RANGE SUBSTATION.

(One and a half miles north-northeast from Paso Robles, San Luis Obispo County. Elevation, nearly 800 feet.)

There have been several changes at this substation since the issuance of the last report. The Patron, Mr. F. D. Frost, resigned in 1900, and his place was taken by Mr. S. D. Merk. Mr. J. W. Neal was transferred here from the Amador substation in 1901.

History.—The substation near Paso Robles was one of the three first established, and has cost more in proportion to positive results than any other of the outlying substations. It was located upon soils typical and varied, in the oak country east of the Salinas River, in a region which was at that time (1888) just changing from long-continued pastoral conditions and the large Spanish ranches of pioneer days, to small farms and modern agricultural problems. Long-delayed currents of life overflowed the region, and large sums of money were wasted by the settlers on crops unsuitable to the soil and climate. If the substation had been established even five years earlier, it might have been able to prevent a large part of these losses; or if it had been established five years later, the experience of others would have been a useful guide to early substation investments. As it was, the history of the place is very closely linked with that of the community; and as will be seen in a bulletin on "Deciduous Fruits in the Upper Salinas," the work of the substation has been by necessity extended over a large area. Other notes upon the recent work of this substation will be found in an account of the Australian and other saltbushes.

LEGEND FOR CHART 1897-8. (See next page.)

At the time that the substation was established, the entire upper Salinas country from San Miguel southward, was taking strong hold of fruit-growing industries, expecting to follow in the footsteps of the Santa Clara Valley in the matter of prunes, apricots, peaches, grapes, and even, as some writers then maintained, olives, oranges, lemons, walnuts, and figs. An ample experimental orchard and vineyard were therefore established, and as different varieties failed others were tested, from year to year, until between 1889 and the present time almost every variety and certainly all types of deciduous and other fruits that offered any

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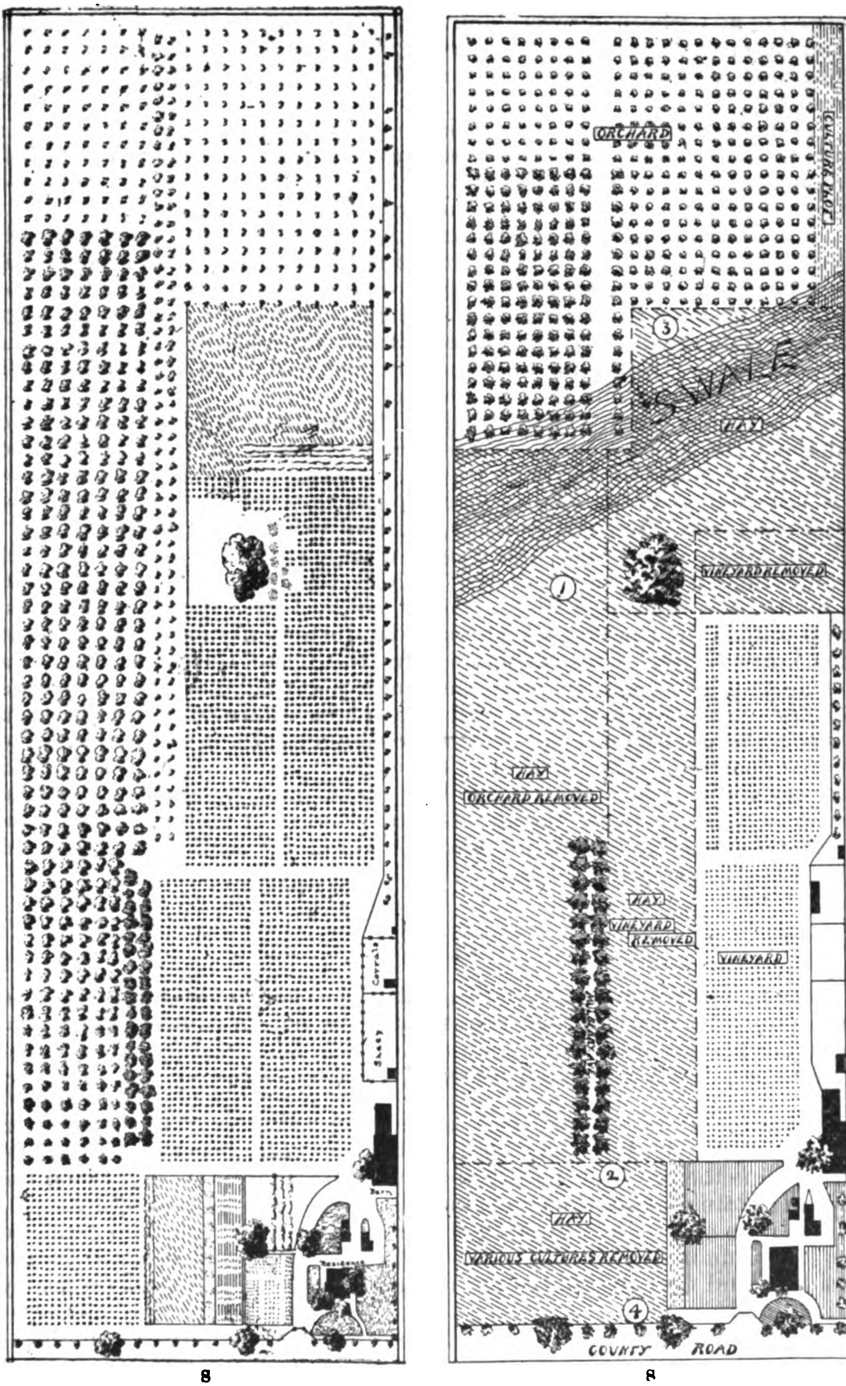

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1897–8. 1901.

PLATE 3. CHARTS OF SOUTHERN COAST RANGE SUBSTATION.

prospect of success have been grown here. The last large planting consisted of an orchard of several hundred selected varieties of apples, pears, and other hardy fruits, which is not yet in bearing, but soon will be. The labor of years in these lines has yielded some very valuable positive results.

From the time that the substation began work, there have been experiments with forage plants and grasses and with whatever vegetation promised to endure the difficult climate and the poor soil. Some of these have given positive results of great value to the region.

A continuous effort has been made to obtain trees and shrubs whose root systems or habit of winter growth is such that they will penetrate the hardpan, which on a large part of the substation soils offers the greatest obstacle to successful agriculture. This hardpan area has been mapped, its thickness measured, and its nature studied. There is much of such soil in California, and the crops possible upon it are often still further limited by climatic conditions.

The years of light rainfall which have occurred since 1888 have enabled the substation to make some important and indeed unique records for maintaining plant growth in seasons of drought. In seasons of sufficient rainfalls, the very complete tests of cereals and many cultures made here have been of recognized value to the district.

The conditions which prevail over a large portion of the area east of the Salinas River, known as the Estrella plains, in San Luis Obispo County, now indicate a wise tendency toward larger, not smaller farms, and toward the pastoral use of much land which has been proven unfit for horticulture. The substation's greatest future usefulness lies in its securing a larger area of land, and there planting those forage plants and those shrubs and trees which have been shown to succeed here, so as to make the pastoral side of its work more important and more nearly self-supporting. The area along the upper Salinas subject to irrigation is very limited; it is the vast rolling plains and uplands east of the river which constitute the agricultural problem of to-day. Here, also, continued experiments with cereals, particularly with new cross-bred varieties, are very desirable.

CLIMATE.

The record of temperature at the substation now covers thirteen years; the rainfall record has been kept for this district for sixteen years, and more or less accurate notes upon climate during an earlier period, reaching back to 1850, have been secured.

Record of Trees.—Three large oak trees growing near the substation were cut in 1899, 1900, and 1901, and the rings of growth examined to determine the probable nature of previous seasons. These grew on the rolling plains east of the river, and the species was *Quercus lobata*. All three were mature and growing trees ranging in age from two hundred to two hundred and fifty years. One specimen was decayed in the middle, and thus part of the record was destroyed. All stood on nearly level land.

In these three trees the annual rings of wood varied greatly in thickness. All showed years of excellent growth, years of medium growth, and years of very scanty growth. In all three, rings of wood of more than average thickness were deposited for one and occasionally for two seasons after the following winters: 1841–2; 1849–50; 1861–2; 1875–6; 1879–80; 1888–9; 1892–3. The periods of smallest wood growth corresponded very closely with the following seasons: 1840–41; 1847–8; 1851–2; 1863–4; 1870–71; 1882–3; 1893–4; 1897–8. Still earlier, there were records on these trees of several years when hardly any wood was deposited, the inference of course being that these years were extremely dry and cold. One such period showed on all three trees, closely following 1795; a much longer and more severe period showed on two of the trees (record of the third destroyed) from 1744 to 1756. From twelve to fifteen extremely thin rings, hardly thicker than the point of a pin, marked this period of tree suffering. Two or three very dry seasons in this decade would have been enough to check growth for a long time, and other natural causes may have been in operation.

The checks to growth caused by such dry seasons as 1863–4 (a very plain record) extended over four and five years. The growths of the two seasons following 1861–2 were collectively greater than those of the six years which came next (1863–4 to 1868–9).

Since the three trees which were examined agree very closely with each other and with the climate record, so far as known for this region, it is fair to conclude that the record for earlier years is no less accurate.

Rainfall and Temperature.—The rainfall does not materially differ over a large area of country east of the Salinas, except that it lessens somewhat as one goes from the river toward the San Joaquin Valley, and increases in the mountains north or south of the broad, rolling plateaus, such as the Estrella or the Carrisa plains. There is little difference in rainfall between Paso Robles and the substation, but what advantage exists is in favor of Paso Robles, at the base of the Santa Lucia range.

At the substation, the season's rainfall has four times since 1888 exceeded 20 inches. The average of fifteen years' rainfall (Paso Robles for 1886–8 and the substation for 1888–1901) is 16.28 inches. This is a very satisfactory average, although averages of rainfall, like means of temperature, must not have too much dependence placed upon them. The following table gives the rainfall by months for four seasons:

Season.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	Totals
1897–8	.08	.56	.05	.23	.82	1.55	.83	.00	.68	4.75
1898–9	.10	.13	.30	.27	4.16	.08	4.99	1.37	.00	11.40
1899–00	tr.	2.55	1.40	2.55	2.11	.08	1.90	.42	.67	11.68
1900–01	tr.	1.54	6.10	.25	6.11	5.37	.63	1.37	1.43	22.80
Average	.03	1.19	1.98	.82	3.30	1.77	2.08	.79	.69	12.65

While the average yearly rainfall for the four years from 1887–8 to and including 1890–91 was 21¼ inches, or enough to justify the highest hopes of success with a wide range of crops, the yearly average for the past four years, as shown in the above table, was less than 13 inches. To be accurate, the average annual deficiency, comparing these two periods, was 8.60 inches against the last four years. The average of fifteen years' rainfall here was a little more than 16 inches, and even this is 5 inches better than the average of the past four years. It is therefore reasonable to expect somewhat better seasons.

The early and late frosts which injure or destroy crops otherwise desirable for this district, must be reckoned with by every practical man. The isotherms, or lines of equal heat—mean annual degrees of warmth—are of comparatively little importance to the farmer; it is the extremes of temperature, daily and seasonal, which are all-important. A maximum of 98° Fahr. and a minimum of 22° Fahr. make the same mean of 60° that is given by a maximum of 107° and a minimum of 13°, but the difference in the resultant vegetation of the two districts is very great.

The lowest temperatures recorded in this region were in 1878, 1886, 1887, and 1888, at Paso Robles and San Miguel (railroad records), when the thermometer once fell as low as 13° Fahr., and several times to 16° Fahr. The substation records show that fruit crops were more or less injured by frosts in nine out of thirteen years. The worst frosts come in March and April, in which months there are often fifteen "killing frosts." In 1892–3 there were forty-two, and in 1898–9 twenty-eight such frosts. The frosts of January and February do little or no harm to fruit. But frequent warm days in February bring out the blossoms early in March, so that anything below 34° Fahr. then injures or destroys almonds and apricots, while anything below 32° Fahr. sweeps off the cherries and peaches. It is of course the April frosts that are the most deadly.

"Smudging" has been experimented with in every form, but proves of no value here where the frosts are so prolonged and so severe over so large an area of rolling country. The total "subject to frost" period has ranged from 200 to 242 days, in the latter case extending from September 21st to April 20th. Irrigation on a small scale, around a few trees, the use of straw on the surface, whitewash on the trees, and every other suggested method of retarding the blossom period of fruit trees failed to have an appreciable influence against the high February maxima of temperature.

The following table continues the record given on page 281 of the last report (for 1897–8):

TEMPERATURE STATISTICS, 1899–1901.

Month.	Daily Mean.	Mean Daily Max.	Mean Daily Min.	Mean Daily Range.	Extreme Max. and Dates.	Extreme Min. and Dates.
1899—July	70.22°	89.00°	51.45°	37.55°	102°—10th	45°— 7th
Aug.	65.59	80.29	50.90	29.39	88 —28th, 29th	44 —16th
Sept.	69.20	88.10	50.56	37.54	97 —13th	44 — 6th
Oct.	58.80	70.58	47.03	23.54	93 — 8th	39 —29th
Nov.	54.35	62.73	45.96	16.76	69 —13th	37 —27th
Dec.	47.29	59.77	34.83	24.93	67 —24th, 25th, 26th	25 —28th
1900—Jan.	49.80	60.96	38.64	22.32	69 —18th, 19th	28 —11th
Feb.	50.28	65.35	35.10	30.39	77 —17th	27 — 8th
Mar.	57.12	71.41	42.83	28.58	82 —30th	32 —28th
April	53.26	68.93	37.63	31.30	87 —17th	27 — 9th
May	64.38	82.03	46.74	35.29	96 —21st	40 —11th, 25th
June	68.50	86.50	50.53	35.96	99 —19th, 20th	43 —15th
July	70.22	90.51	49.93	40.58	106 — 8th, 9th, 12th	45 —22d
Aug.	67.12	84.06	50.22	33.83	110 — 2d	42 — 9th
Sept.	63.33	82.13	44.13	38.00	100 —22d	36 —25th, 26th
Oct.	59.67	74.93	44.77	30.19	90 — 9th	27 —30th
Nov.	56.23	71.13	41.36	29.76	87 —12th	31 —13th
Dec.	45.58	59.64	31.54	28.09	71 — 6th	18 —31st

TEMPERATURE STATISTICS, 1899-1901—Continued.

Month.	Daily Mean.	Mean Daily Max.	Mean Daily Min.	Mean Daily Range.	Extreme Max. and Dates.	Extreme Min. and Dates.
1901—Jan. ..	46.61	57.03	36.22	20.80	68 —19th	17 — 1st, 2d
Feb. ..	50.85	60.60	41.10	19.50	74 —28th	24 — 7th
Mar. ..	52.70	66.90	38.51	28.38	78 — 1st	29 —29th, 31st
April.	53.76	70.46	37.10	33.36	84 —19th	28 — 7th, 8th
May ..	60.54	75.90	45.22	30.67	94 —31st	36 —20th
June.	66.43	87.26	45.60	41.66	110 —28th	36 —10th, 13th
July ..	73.64	94.87	52.74	43.74	106 —19th	44 — 3d
Aug. ..	72.29	92.32	52.25	40.06	109 — 2d	40 —24th
Sept. .	63.03	82.43	43.63	38.80	98 —16th	38 — 8th
Oct. ..	62.99	80.48	45.41	35.06	96 —13th	36 — 2d
Nov. ..	54.60	67.40	41.88	25.53	83 — 5th	32 —13th
Dec. ..	44.74	60.35	29.12	21.22	68 —31st	16 —13th

The number of "killing" frosts during this period was as follows: From December, 1899, to April, 1900, inclusive, thirty-six; from October, 1900, to April, 1901, inclusive, forty-seven; November and December, 1901, twenty-two. The total for the two years was one hundred and five, and in January, 1902, there were twenty-two more.

The temperature record has been kept at this substation since it was established, and with a maximum and minimum thermometer, and in recent years a self-recording instrument. Orchards and gardens here and there escape frosts; one notable Paso Robles case is that of Mr. Brentlin, half a mile from the substation, on a northeastern slope. West of the Salinas, in the foothills, are many locations which appear to be frostless, but a great deal of the region east of the river, and not a little west, is subject to late spring frosts. It will take years of close observation to determine with any certainty the "frostless areas"; but only by doing this can the "safety points" be ascertained for many kinds of fruits.

THE ORCHARD.

The history of the orchard has been fully set forth in a separate bulletin entitled "Experiments with Deciduous Fruits at and near the Southern Coast Range Substation from 1889 to 1902." It is only necessary, therefore, to give some observations which do not appear in that bulletin. These refer principally to the very promising young orchard planted in 1897 at the northern end of the substation on both the brown and the black adobe soils beyond the swale.

Apples.—In the young orchard, Ivanhoe, Terry, Eureka, Gold Ridge Winter, Swaar, Red June, Seek-No-Farther, Duffy's Seedling, and Bethlemite bore for the first time in 1901. All of these, excepting Red June and Swaar, are new to this district and to the substation.

The best of all these varieties is Gold Ridge Winter, a California seedling, obtained in 1896 from Sebastopol, Sonoma County, through the courtesy of Mr. Fred W. Gill of that town. This fine yellow apple has not been listed yet in any catalogue. The young tree bore eighteen large apples, which were gathered October 5th and kept until the end of December. This variety, therefore, bids fair to give the district east of the Salinas a better keeper than has been known before, as even the Yellow Newtown Pippin is fully ripe by November 1st on these soils east of the Salinas. The quality of Gold Ridge Winter is very fair, and if grown nearer the coast the apple would rank high. It is as good as any apple grown on the substation, and better here than either White Winter Pearmain or Yellow Newtown Pippin.

Among the other new apples, Ivanhoe proved of medium size, a smooth, red-streaked variety that kept only until the middle of October. Eureka, Swaar, and Seek-No-Farther all ripened before November. Terry kept better, but is a small apple. Bethlemite and Duffy's Seedling are not suited to the climate.

In the old orchard in or near the swale, a few apple trees planted in 1899 are now bearing well. Peck's Pleasant, Red-Cheeked Pippin, Early Ripe, Duke of Devonshire, Maiden Blush, Baldwin, Stark, Calvert, Haas, Acme, Shackelford, Huntsman, Lankford, and Montreal Beauty Crab, all bore crops of from 35 to 90 pounds per tree in 1901. Some twenty varieties bore smaller crops of poorer fruit, and need not be listed here. The trees are healthy, and excepting in years of extremely severe and late frosts bear well. The fruit ripens very early, as noted in previous reports, and is not of high quality; but for family use, some varieties of apples are undoubtedly worth planting in selected localities east of the Salinas.

In most cases all these apples began to fall from the trees by October 1st, and had to be gathered. Some varieties in other districts, known as autumn and early winter sorts, ripen by the middle of September. Of the varieties in the older part of the orchard, the best in 1901 were Peck's Pleasant, Marshall's Seedling, Acme, Lankford, and Montreal Beauty.

Pears.—In the young orchard, a few blossoms formed on Lincoln Coreless and several other varieties, and a few pears ripened, but not enough to test any sort. On the older trees on the swale and north on the brown adobe the best crops were on Conseiller de la Cour, the fruit of which kept until late in January; Beurré Gris d'Hiver, which also was a January pear; Nouveau Poitou, which ripened late in December; Doyenne du Comice, which was in its prime at Christmas; Bartlett, which was at its best in September; and Winter Nelis, here a December pear. Some of the Bartlett trees bore 150 pounds apiece. The quality of all the pears was of highest grade. The pears grown here would rank as unusually good in flavor and color in any market. In years of average rainfall, they are of large size.

Plums and Prunes.—The trees yielding best, all on swale soil or northward on brown adobe, were, in 1901, Robe de Sergent Prune, Red Egg, Barry, Petite Prune, Datte de Hongrie, Burbank, St. Catherine, and Bulgarian, also the Myrobalan; but none of these, except the last, bore more than 25 pounds to the tree. Most of these plums bore early for the variety, and none of them except the Myrobalans are holding their own. The only plums for this district are Americanas, and hardy, half-wild types, from which a good deal can be expected.

Other Fruits.—Quinces are beginning to bear in the young orchard, and there is no reason why they should not succeed in this district on good soil. Almonds, apricots, peaches, and nectarines did nothing in 1901. The district east of the river is generally unsuited to almonds and apricots; peaches and nectarines, with care and in chosen spots, do quite well in ordinary seasons. The only mulberry of value for home use here is the Persian, which is both hardy and of very good quality. It should be planted by every land-owner in this region.

Growth of Trees on Hardpan.—A summary of the condition of fruit trees on hardpan for three years before most of the orchard was removed, or in 1898, 1899, and 1900, shows the following facts: The average annual growth of the cherry tree was 4½ inches; of the almonds, 5 inches; of the peaches, 8 inches; of the plums, 9 inches; of the apricots, 10 inches; of the pears, 18 to 20 inches. Some trees hardly added two inches a year to the length of their branches. There were almost no suckers or fresh side growths to renew the heads.

In every case when trees were removed, the depth to hardpan was recorded. The cherries taken out since 1898 had from 20 to 27 inches of soil above the hardpan. The almonds had from 21 to 25 inches. The apples had from 18 to 24 inches. The plums and prunes had from 16 to 30 inches. Some of the trees taken out at the final clearing in 1901–2, left longest because making the best appearance, stood on a little deeper soil—not over three feet.

THE VINEYARD.

The following table shows growth and yield per vine of leading varieties of grapes on light soil underlaid by hardpan. If planted on stronger and deeper soil, of which there is much in the district, and more especially if planted well up on the hillsides, the growth and yield of a vineyard would undoubtedly be much more satisfactory. In many seasons the late frosts destroy, or at least shorten, the crop of this hardpan vineyard. The crop is usually shortened by the ravages of birds, which attack all kinds of fruit. The vines whose crop was weighed were those which had been least severely attacked:

GRAPES IN 1901.

Variety.	Average Season's Growth of Canes.	Yield per Vine.
Verdelho	2 feet.	2 lbs.
Meunier	3 "	2 "
Cinsaut	3½ "	4 "
Gros Mansenc	3 "	2 "
Carignane	4 "	5 "
Bastardo	3½ "	3 "
Blue Portuguese	2½ "	2 "
Tinta Amarella	4½ "	6 "
Black Morocco	4 "	8 "
Pinot St. George	3½ "	6 "
Golden Chasselas	4½ "	7 "
Folle Blanche	3½ "	5 "
Serine	3½ "	6 "
Crabb's Black Burgundy	4½ "	8 "
Sultana	3 "	2 "
Verdal	4 "	5 "
Tinta de Madeira	4½ "	6 "
Herbemont	3½ "	4 "
Malbec	4 "	8 "
Chauché Noir	3 "	1 "
Pizzutello	6 "	8 "
Muscatello Fino	4 "	5 "
Robin Noir	3½ "	7 "
Burger	4 "	5 "
Petit Bouschet	3½ "	6 "
Mataro	2½ "	6 "
Huasco	2 "	4 "
Charbono	2½ "	1 "
California Black Malvoisie	4½ "	8 "

Out of sixty-six varieties, reported upon by the foreman in 1901, none yielded more than 8 pounds to the vine. The strongest grower by far was Pizzutello, here one of the best table grapes and one of the best bearers of the whole collection. Hundreds of cuttings of this grape, as well as of Black Morocco and others that promised well here, have been distributed in the region.

PERENNIAL GRASSES.

Roots of many perennial grasses were sent to the substation in 1899, to test their drought-resistance. They were planted in plots, irrigated once or twice to give the roots a foothold, and were afterward cultivated. Nearly all failed to endure the summer. *Andropogon citratus* (lemon-grass) died down, but sprouted again with the first rains, and by December 1st was from 8 to 12 inches high. This is a valuable early winter grass for the region. Another which grows in much the same way here is *Panicum altissimum* (tall panic). *Paspalum compressum* also started with the first rains, but made very little growth.

The late frosts, April 10, 1900, injured *Paspalum dilatatum* (large water-grass), also the rye-grasses, also *Phleum pratense* (timothy), *Panicum bulbosum*, and *Agrostis vulgaris* (red top). It was too dry for any of these. Bermuda-grass was also frosted, but recovered and started again, keeping green until autumnal showers, when it grew quite well.

Panicum molle (para-grass) kept green until the early rains, but only grew slowly in winter. *Sporobolus wrightii* made a growth of 4 to 5 feet, and bloomed. Cut back, it grew again the following season.

Bouteloua curtipendula (the side-oats grama of Nebraska) made a fair growth and kept green all summer. It grew poorly in winter and died the next season. *B. juncifolia* is the only one of four species of grama-grass which has stood three seasons.

Eragrostis tenuis (branching spear-grass) kept green all summer, and so did *Elymus arenarius* (sea lyme-grass), *Elymus triticoides*, a Pacific Coast species, *E. canadensis glaucifolius*, *Agropyrum pseudorepens* and *A. spicatum*, also *Lygeum sparteum*. One of the best of all the grasses grown was the many-flowered millet (*Oryzopis miliacea*), which remained green all summer and made a large winter and spring growth.

Seventy-two species were grown in all, thirty-two of which died before the end of the first season, and fifteen proved too tender.

WHEAT EXPERIMENTS.

In addition to the experiments elsewhere described with gluten wheats, etc., four plots were sown in 1900–1901 to White Australian wheat, three of which were variously fertilized for hay crop. All were sown December 10th, and cut May 31st. The results were as follows:

	Thomas Phosphate per Acre.	Sodium Nitrate per Acre.	Yield of Hay per Acre.
Plot 1	500 lbs.	180 lbs.	6,225 lbs.
Plot 2	500 "	....	4,395 "
Plot 3	....	180 "	7,087 "
Plot 4	....	....	2,669 "

The considerable difference between plots 1 and 3, which is more than ten per cent, is doubtless due to differences of soil, though in appearance the plots were the same.

In 1899 there were field tests made of fifty varieties of wheats, including thirteen Algerian varieties and a number of cross-bred sorts from Australia. Sown January 9th, and heading out after May 10th, the ripe wheat was cut from July 11th to July 28th. The stalks ranged in height from 22 to 37 inches; and the heads varied in length from 2½ to 4½ inches.

The crop, in drilled plots, ranged from a rate of 907 to 5,142 pounds per acre. All the Algerian wheats, such as Hamra, Adjini, and Chetta, yielded above the average, and ripened among the earliest. King's Jubilee Improved Fife yielded at the rate of 4,235 pounds per acre, and was very early. Ratling Jan × Hornblend and Indian was nearly as early as any, and gave a yield of 4,537 pounds per acre. Steinwedel × Quartz and King's Jubilee and Steinwedel and Amethyst × Hornblend and Early Baart, also Cujanian, Clawson, and Chili, were among the best. No. 30 American Select yielded more than any other variety, or at the rate of 5,142 pounds per acre, and ripened July 14th. Pride of Genesee, Turkish Red, and Currell's Winter did not ripen until the end of July, and did very poorly for drilled plots, being less than one fourth the crops of the better varieties named.

This experiment showed early the great difference in varieties grown here, and the value of some of the new cross-bred wheats. Reviewing the work of the substation since its establishment, on cereals, it may be said, briefly, that a very large number of varieties of wheat, barley, rye, spelt, and millet have been grown here, on both the granite hardpan and the deep adobe soils. The region in years of average rainfall is exceedingly well adapted to cereal crops. The substation has steadily practiced early planting on well-prepared ground, drilling, and breaking of the crust when needed. The resultant crops on small plots have been exhibited at County and State fairs on numerous occasions. Seed of the best varieties has been locally distributed. There is an increasing demand for a continuance of experiments with cross-bred wheats, barleys, and other cereals, in order to secure greater drought-resistance and better yield, and this is one of the most hopeful lines for future work.

Wheat Hay Experiments.—The question being locally asked of the substation, whether "it made much difference what kind of wheat was sown for hay," a series of plots were laid out in 1898–9—some on the swale soil, which was too wet to be sown until January, and some on the lighter soil. The results were surprising to the district. In every case, the plots were broadcasted. The following table shows results. No fertilizers were used, and the soil was uniform, having shown in previous years, when sown to one variety, no appreciable difference between plots. As the late rains were abundant, the plots on the light soil came out very well, although sown so late. In the case of the hardpan soil, it is in wet years impossible to plow early, as horses can not walk on the surface.

Variety.	Soil.	Sown.	Cut.	Yield per Acre.
Hornblend × Indian G.	swale	Jan. 4	May 22	2,820 lbs.; few leaves.
Hornblend × Early Baart R.215	"	" 4	" 22	2,980 lbs.; few leaves.
Marjorica Carusa × Blount's Fife and Ward's Prolific	"	" 4	" 25	3,610 lbs.; excellent hay.
Marshall 8 × Gypsum and Ward's White	"	" 4	" 25	4,300 lbs.; excellent hay.
White Sumatra × Ward's Prolific	granitic sand	" 21	" 23	2,774 lbs ; excellent hay.
Sonora	" "	" 21	" 22	3,000 lbs.; fair hay.
Steinwedel × King's Jubilee and Indian A	" "	" 21	" 25	3,030 lbs.; fair hay.
Jacinth × King's Jubilee and Leak's	" "	" 21	" 25	3,105 lbs.; excellent hay.
Ward's Prolific	" "	" 16	" 25	5,150 lbs.; excellent hay.
Frame's New × Australian	" "	" 16	" 25	6,570 lbs.; best of all in quality.

SEEDS FROM WASHINGTON, AND ELSEWHERE.

A number of introductions, chiefly sent out by the Department of Agriculture, have been tested here, and some of the more promising cultures are being continued.

Ryes.—No. 4343, Abruzzi, from Naples, was sown December 1, 1900, and required fourteen days for germination. It came up evenly, and made a good stand. It headed out by March 20, 1901, and was harvested and threshed in July, yielding a fairly good crop.

No. 5031, Schlousted Winter Rye, sown at the same date, December 1, 1900, also germinated in fourteen days. This variety headed by April 20, 1901, yielding very fairly for the amount of straw.

No. 5058 was sown on the same date, also requiring fourteen days for germination. This kind headed by May 10th, yielding fairly.

These three ryes were distributed by the Central station in 1901.

Wheats.—No. 3823 (original seed of Gluten Wheat) was sown December 10, 1900, and required from twenty-eight to thirty days for germination. This germinated poorly and grew very slowly, but headed by May 22, 1901. It was harvested early in July and seed saved, some of which was sent to Washington, and some to Berkeley. Another plot was sown in the fall of 1901 from this seed, which was somewhat shriveled and small.

No. 3823*a* (the first-remove California-grown wheat) was sown December 10, 1900, requiring sixteen days for germination. It started well, made a good growth, headed by May 19, 1901, was harvested early in July, and threshed. The grain was more plump and larger, and contained more starch than the original seed.

No. 5486, "Dawson Golden Chaff," sown December 10, 1900, required sixteen days for germination. This germinated well and grew well, although slowly at first. It headed by May 14, 1901, and was harvested early in July. The grain was plump and full and yielded a heavy crop.

No. 5493, "Fultz," was sown December 10, 1900, and germinated in sixteen days. It headed by May 14, 1901, and was harvested early in July.

No. 5486 was sown December 10, 1900; it germinated well and made good growth. It headed by May 14th, and was harvested early in July. This grain was plump and full, heads being well filled.

No. 5145 (from Missouri Experiment Station) was sown December 29, 1900, and germinated very slowly and poorly. The land was very wet and much of the seed rotted in the ground. What grew headed by May 25, 1901, and was harvested early in July. The heads were well filled and grain was plump and full.

Barley.—No. 5590 was sown December 20, 1900, and germinated in twenty days. It made a thick, heavy growth, headed by May 1st, and ripened by June 5th. This was cut and threshed by July.

No. 5592 was sown December 25, 1900, and germinated in twenty days. It made a heavy growth, headed April 26, 1901, and was ripe by June 1st.

No. 5793 (Moravian or Hanna) was received late, so was not sown until February 27, 1901, but germinated in seven days, making a good stand. It headed by May 25th and was ripe June 15th. This gave a very heavy crop.

Vetches.—All the vetches noted in the chapter on the Sierra Foothill Station have been tested here for several seasons. *Vicia narbonensis* (No. 1509), sown November 24th, bloomed March 20th, and made fair early growth, but dried up by June 1st and did not mature seeds. No. 1507 was not injured by the spring frosts, but made small growth. The one best adapted to the region is the Hairy Vetch, which has been grown alone and mixed with rye or oats. Sown in November or December, it germinates in from fifteen to eighteen days and can be cut for hay the first week in June. Hairy Vetch sown November 8th with Russian rye (No. 1342) did very poorly; sown with oats (No. 1178) the same date, it made an excellent stand.

Egyptian Clover.—Nos. 4254 and 4256 were sown December 21, 1900, and required twenty-one days for germination, which was good in both varieties. Both made good growth for a time and stood three inches high, when both were badly injured by April frosts and the foliage killed. The stems survived and began to put forth new growth, but finally died without making any growth to speak of.

The district is as a rule too cold for this plant. In 1899, however, it was the best clover grown at the substation; but in 1899 many clovers grew very well.

Cañaigre.—The cañaigre now growing on the substation is from seed sown in the spring of 1899 and planted out in rows January 3, 1901, when the roots averaged six to the pound. The tops died down during the summer, but new growth came up after the rains set in and was from eight to ten inches high by the end of February. Cañaigre does well here.

Dwarf Essex Rape.—Seed of this well-known forage plant was sown November 26, 1900, and germinated in nineteen days. By April 1, 1901, it averaged eighteen inches in height. A portion was then cut, and yielded at the rate of over 9½ tons per acre. By May 7th it averaged over two feet in height. A portion was then cut, and yielded at the rate of over 15 tons per acre. At this time many of the plants were in bloom, and the stalks were woody. Cows rejected the ends of the stalks, but sheep ate stalk and all. The portions cut April 1st and later, made new growth of over one foot high by June 1st. This new growth continued green all summer, and cows, horses, and sheep kept feeding on it, and when the ground was broken up for hay in December, the roots were still green and throwing up new growths. This rape promises to become a very profitable plant to cultivate in this district.

March Rape.—No. 1449, from the Department, was sown November 10, 1899, and germinated in ten days. It began to bloom March 4, 1900, when only six to eight inches high. The Dwarf Essex Rape is much better adapted to this locality. Sown the same year, on October 25th, the Essex Rape germinated in six days and stood eighteen or twenty inches high by March 1, 1900. When cut for hay during April it yielded 13 tons of green fodder per acre. As noted in the preceding paragraph, Essex Rape did even better than this the following season, 1900–1901. At Amador substation, however, March Rape far surpassed the Essex.

Turkestan Alfalfa.—Nos. 1150 and 1151 were sown November 11, 1899, each taking nine days to germinate. Both made short growths, averaging about six inches, and were pretty well dried-out by May 25th, but the roots survived and started again the following winter.

Bromus inermis (No. 3004).—This grass, sown November 8, 1899, requiring twelve days for germination, made a short growth and was dried up by June 1, 1900. In some years this grass remains green until August. It is worthy of extended planting.

Russian Millet.—No. 1387 was sown March 21, 1900, and required fifteen days for germination. It was irrigated several times, headed by June 5, 1900, and ripened by July 26th. The yield was very poor.

Broad Beans.—No. 1454 was sown November 11, 1899, germinated November 26th, and bloomed March 17th when three feet high. Destroyed by frosts of early April and subsequent hot weather. All beans of this class have failed here, chiefly by reason of late spring frost.

Lentils.—Nos. 1466 and 1483 were sown at various times, as also a collection from Vilmorin, and the noted Big Hiller Lentil of the Volga region. Sown late in November, they bloom about the end of April and make a good early growth, covering the ground. The heat of summer dries them up, and they seldom mature seed.

Goat's Rue.—No. 1456, sown November 27, 1900, made very poor growth. Some remained green until the following August. Goat's Rue will not stand the summers here.

Safflower.—No. 1343, sown December 4th, grew three feet high, bloomed May 30th, and kept green until autumn.

Foxtail Furze.—No. 1446, sown November 11th, germinated December 12th, and grew ten inches high the first season. It stood the dry weather very well, and seems worthy of extended trial.

Alfalfa from the Estrella.—Seeds of a selected alfalfa from Mr. J. Marden, of the Estrella, said to be quite resistant, sown November 15, 1899, has stood the dry weather better than did the Turkestan. All the varieties of alfalfa tested here required some water in summer to carry them through.

Iris pabularia.—Widely advertised as a dry-land forage plant. Its leaves die down to the ground here by the middle of July, but the roots remain alive.

Lathyrus sylvestris (No. 1460).—This pea has been grown here for a number of seasons. It must be sown early. It makes poor growth, but remains green without irrigation until the end of July.

Rye-Grasses, Clovers, etc.—A collection of rye-grasses from Sutton & Co. was sown here November 24, 1899. All need irrigation to keep alive. The same is true of white clover, red clover, yellow trefoil, *Triticum scabrum* of New Zealand, *Cynosurus cristatus*, and a great number of well-known forage plants. Schrader's Brome-grass (*B. unioloides*) will grow two feet high in ordinary years, ripening seed in June, but dried up by June 30th. *Elymus glaucus* (wild rye) makes a good stand and will in some seasons stay green until July. *E. canadensis* and other species tested here were about the same as *E. glaucus* in drought-resistance, excepting *E. condensatus* (giant rye-grass), which kept green in 1899 until autumn without irrigation, far surpassing in this respect *Bromus inermis*.

Jersey Kale.—This plant, after many years' trial here, is found to stand the dry climate reasonably well, and it keeps green all summer without irrigation. Livestock eat it readily and it is much used in the vicinity as green feed for poultry.

Saltbushes.—*Rhagodia nutans* and *R. spinescens inermis* grow moderately well here, but the latter is much better than the former. *Atriplex cachiyuyum*, *A. pamparum*, and *A. nummularia* are all doing well on the substation. These make very heavy growth and stand the dry climate superbly. When measured May 7, 1901, plants set out from seed boxes May 23, 1900, were in size as follows:

	Best Plant.		Average.	
	Height.	Spread.	Height.	Spread.
Atriplex nummularia	26 in.	20 in.	20 in.	15 in.
Atriplex pamparum	18 "	36 "	14 "	30 "
Atriplex cachiyuyum	16 "	36 "	12 "	30 "
Rhagodia spinescens inermis	27 "	30 "	18 "	18 "
Rhagodia nutans	10 "	20 "	6 "	14 "

These saltbushes were cultivated but not irrigated since transplanting. They have not suffered from frost, although the temperature fell to 17° Fahr. three nights in succession in January, 1901.

VEGETABLES.

The climatic conditions are well shown by the foreman's notes on a small vegetable garden in 1899 and 1900.

Radishes (scarlet turnip) sown February 13th were ready for use March 25th. Sown October 2d, were fit to pull October 25th. White Chinese and Osaka radishes sown October 2d were ready for use November 10th, and so continued until March 10th. Radishes sown in March were valueless.

Lettuce in large variety sown February 13th, made excellent heads by May 1st and were used until June 10th. Volunteer lettuces starting with the October rains were fit to use by Christmas.

Onion sets planted February 14th were used March 25th. Onion seed planted the same day grew, but the plants failed.

Carrots, turnips, table beets, and garden peas, sown February 14th and March 28th, also failed to mature. Rostow sugar peas sown January 28th, however, made a start and peas were fit for use May 10th. Rutabagas in variety did better than the white turnips. Carrots sown October 2d were ready for use January 20th.

Spinach (Victoria), also sown October 2d, was fit to cut February 10th, and "yielded four crops."

Garden beets sown in October failed to mature.

Purple-top turnips sown October 17th were of marketable size February 10th.

As these brief notes show, early planting is needful in this district. It is the universal experience of farmers here that by planting gardens with the first rains, they can have a great variety of choice vegetables in the spring months.

MELONS AND SQUASHES.

The watermelons grown in this region are generally of excellent quality, but muskmelons do not do as well; the vines, as well as those of squashes, suffer from sunburn. The following notes are mainly from those taken by the foreman, Mr. Barber, on various melons, etc., grown in 1900. All were on good soil, none on "hardpan."

Kleckley Sweet (Watermelon).—Seed planted March 31st, germinated twenty per cent April 20th. The first melon was ripe August 28th. Long, narrow oval in shape, dark green, with thin rind. Flesh red, tender, crisp, juicy, sweet. Fine quality and flavor. Seeds white. Weight up to fifteen pounds. Did not bear well.

Fordhook Early.—Planted March 31st, germinated eighty per cent April 19th. First melon ripened August 5th. A broad, irregular oval melon, jade-green and mottled; rind thin. The early melons were of poor quality, juicy but not sweet, with a hard core. The later ones were much better, tender, juicy, and sweet, with red flesh and good flavor. Seeds white. Weight up to eighteen pounds. Bore well.

Hungarian Honey.—Planted March 31st; germinated sixty per cent on May 4th, a very slow germination—seed probably old. The first melon ripened August 20th. It was very small, round, dull green, and mottled. The rind was thin; flesh tender, juicy, and very sweet. Flavor excellent. Seeds brown. Vines poor bearers and fruit too small for market. In some seasons and places the melons of this small, round type are among the most popular for local consumption in the Coast Range towns, weighing from five to ten pounds. At the substation this melon has never been large, but it was one of the best a few years ago in the Willow Creek district.

No. 4269 of the Department of Agriculture.—The melon received under this number from Washington came originally from Monetta, South Carolina; was also named the "Mathis." It belongs to the Kolb Gem type, and was said to be a fine shipper. Sown April 12th, only one seed germinated, May 4th, and was destroyed by squirrels.

No. 1194 from the Department of Agriculture.—This interesting watermelon from Sarmakand, Russian Turkestan, was sown March 31st. One hill grew, May 4th, and the first melon ripened August 5th. The fruit was globular, pale green, with slightly darker stripes; rind thin; flesh pink, very tender, crisp, juicy, sweet, and "melting like sherbet." Quality in all respects very fine. The melon was very small, however. The seeds were black and small.

Other watermelons received from the Department of Agriculture were No. 1070, a variety from Kief, known as the "Monastery"; No. 1089, from Odessa; and No. 1220, from Tashkent in Turkestan. The first of these three was an excellent, small striped melon, but rather late. The others did not germinate. The largest of all the melons received from Asia was No. 727, from Udjarri, between Tiflis and Baku, Transcaucasia; a large, green-striped fruit weighing up to eighteen pounds. The flesh was pink, with a tinge of yellow, and seeds were black. It had no advantages over the best American varieties.

Kolb Gem, a well-known sort, sown March 31st, germinated seventy per cent April 30th, and melons ripened June 25th, thus beating Fordhook First by eleven days. The fruit was of excellent quality. The weight varied, up to twenty pounds.

Honcharenko.—This was a small but very fine melon obtained from Agapius Honcharenko, near Haywards, in Alameda County, and was distributed in the winter of 1900. Sown March 31st, seed germinated sixty per cent April 19th, and the melons were ripe July 29th, beating Fordhook First seven days. This was a round melon of pale green color with slightly darker stripes. The rind was very thin indeed; flesh was light red, crisp, tender, juicy, sweet, best flavor. A good bearer. The weight rose to fifteen pounds in a few cases, though many ran from five to ten pounds. This was one of the best melons ever grown at the substation.

The Small-Seeded Melons.—There is much resemblance between the three small, round melons, Hungarian Honey, Honcharenko, and No. 1194 from Sarmakand, and the last-named, the smallest of the three, may well be the original type from which the others came, one by way of the "central route" into northwestern Europe, the other by the way of Asia Minor to Mount Lebanon, whence Father Honcharenko, a priest of the Eastern Church, obtained it. All three melons are highly drought-enduring, the small, narrow leaves curling up edgewise more completely than do the leaves of the larger sorts, and all three are usually prolific.

Pumpkins and Squashes.—The Red Etampes and the Mammoth Tours pumpkins and the Cashaw squash, planted April 3d, germinated April 19th and grew well for a time, but were attacked by "wilt disease," and only the Cashaw squash survived, making a poor growth and yielding only a few squashes.

THE SAN JOAQUIN VALLEY SUBSTATION.

(One mile southeast of Tulare City, Tulare County. Elevation of site above sea-level, 282 feet.)

This substation, perhaps more nearly than any other, is the direct outgrowth of a long-continued study of one of the greatest of agricultural problems. "Alkali lands," which are rendered more or less unfit for use by reason of an excess of salts of various sorts, exist over large areas and in many parts of the world. In the San Joaquin Valley and other portions of California the presence of surplus alkali constitutes the chief difficulty of the land-owners, and efforts to conquer it date back to the beginning of agriculture in these regions.

Alkali soils were discussed in the biennial report of the College of Agriculture for 1875–6, page 43, and again much more in detail in the following biennial, 1877–8, pages 30–39. As the great importance of the subject has become manifest in succeeding years, more and more attention has been given to it by the California station, so that the bulletins and portions of reports on the subject issued in the past twenty-five years would form, if collected, a large volume.

The Tulare substation, established in 1888, has since that date tested an enormous number of different species of plants on various grades of alkali. The results are scattered throughout recent publications, and form the most complete series of such experiments which have been made in the United States. Over and over again seeds are received as "new in the San Joaquin Valley," or "worth trial there," which were long ago given a thorough test and found worthless. None of the cowpeas (*Vigna catjang*), for instance, are of any avail here, and none of the vetches can be said to succeed on alkali soils; but questions are still asked every year about both cowpeas and vetches, which thrive in the Sierra foothills, twenty miles distant.

The progress of actual work in alkali reclamation and the history by charts of the rise of alkali here, were given in Part II of the report for 1898–1901. The present season of 1902 is in some respects the hardest one for agricultural work since 1888, and results can be shown only on irrigated areas; and not always there, owing to the way in which the heavier alkali soils run together when wet, preventing germination of seeds.

Changes and Improvements.—There has been little money spent on this substation since the issuance of the report of 1897–8. A new well was sunk and a pump and horsepower installed. In order to make irrigation effective, five or six acres should be graded, and a pipe, or wooden boxes, used to carry and measure the water accurately. No changes have occurred in the local officers; Mr. Julius Forrer remains foreman, and Mr. John Tuohy, Patron.

Local Value of the Station.—In 1900 and 1901 the substation made extensive exhibits at the agricultural fairs of Tulare and Kings counties, and distributed bulletins, seeds of saltbushes, etc. The distribution of cuttings of figs, grapes, mulberries, etc., has been extensive for the past ten or more years. A small price is now put on grape cuttings to aid the "sale fund," and the demand increases each year. Local correspondence and number of visitors are greater than formerly.

CLIMATE.

The climate of the region, while healthful, places decided limitations upon plant growth. With water, and wherever the amount of alkali is on the safe side, very large staple crops are grown, and some fruits are extremely successful. There are such large areas where these conditions prevail that the prosperity of the upper San Joaquin as a whole is permanent, but still the areas where plant life suffers are of considerable extent, and in such places irrigation, drainage, and alkali-reclamation are essential.

Rainfall.—The average rainfall for the past twelve years at this point has been 8.37 inches. The average at Tulare City is less than at Visalia, Porterville, or Hanford, all points in the valley within twenty miles distance. Visalia and Porterville are nearer the Sierra, and Hanford, farther west and north, is nearer the ocean and the Coast Range. The following table gives the rainfall in inches at the substation for ten years past and, with the comments which accompany it, illustrates the differences of successive seasons:

RAINFALL (INCHES) BY MONTHS FOR TWELVE SEASONS.

Season.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	Total.
1892-3	.00	.26	.39	1.51	.64	1.20	3.02	.33	.00	7.35
1893-4	.00	.00	.05	1.07	1.24	.38	.77	.09	.26	3.86
1894-5	.00	.18	.02	2.44	3.25	1.23	.86	.60	.60	9.18
1895-6	.00	.43	.98	.36	1.78	.01	.72	.14	.14	4.56
1896-7	.00	.74	1.11	.59	2.43	1.61	1.73	.00	.00	8.21
1897-8	.59	.59	.26	.79	.63	.97	.72	.00	.59	5.14
1898-9	3.75	.01	.16	.19	.92	.14	2.28	.17	.02	7.64
1899-1900	.00	1.35	1.32	1.28	1.02	.10	.77	1.73	2.03	9.60
1900-1901	2.18	.04	2.41	.19	3.27	1.19	.36	1.11	1.87	12.62
1901-1902	.42	.39	.36	.03	.40	2.28	2.14	.74	....	6.76

Such a table as this is difficult to explain to persons unused to the San Joaquin region, but the amount of rainfall is not nearly as deficient as might appear. From 7 to 8 inches—the average of the past thirty years here—is sufficient to produce a crop of cereals, provided that this small amount of rainfall is properly distributed. The amount of winter irrigation needed, therefore, is not great.

It is true, however, that an unfavorable distribution of the rainfall often occurs. In 1898–9 the rainfall of 7.64 inches gave very poor crops, almost a failure, in fact; but in 1892–3 a less rainfall (7.35 inches), well distributed, gave fair and profitable crops throughout this district. Even the large rainfall of 1900–01 (12.62 inches) was so badly distributed (the two inches which fell in September being of little or no value, and the dry March being very bad for grain) that the season as a whole was but an average. The present season (1901–2) entirely lacked early rains sufficient to start plows. Two or three inches of rain in November or December with the February and March rains received would have made large crops. Much of the rainfall of 1899–1900 was of little avail for farmers, and better distribution of the April and May rains would have doubled the crops. The rains of 1894–5 came so as to yield large returns, and those of 1896–7 were also well distributed.

The application of from 6 to 12 inches of irrigation water (from a half acre-foot to one acre-foot) will evidently be sufficient to secure regular cereal and other crops in such a country as this.

Temperature.—The temperature reports from this and other substations appear in the United States Weather Bureau reports, and the leading features of this climate are now well understood. The following table shows the monthly summaries since and including January, 1898:

MONTHLY SUMMARY OF TEMPERATURE.

Month.	Maximum.	Minimum.	Mean Max.	Mean Min.	Mean Tem.
1898—January	70°	20°	58.90°	28.90°	43.90°
February	84	32	72.50	39.71	56.10
March	92	24	74.19	35.54	54.87
April	106	32	87.76	54.70	66.73
May	104	42	85.03	48.98	67.00
June	110	48	98.86	57.40	78.13
July	112	54	104.96	61.87	83.41
August	112	50	103.93	60.85	82.25
September	112	48	91.80	53.46	72.63
October	88	40	82.19	48.71	65.65
November	80	24	69.93	34.26	52.10
December	72	18	60.06	30.19	45.12
1899—January	78	26	63.60	36.00	49.38
February	84	18	70.28	31.85	51.07
March	94	26	69.87	40.15	55.16
April	102	36	80.93	44.66	62.80
May	100	34	82.06	46.06	64.06
June	112	50	96.66	59.40	78.03
July	114	54	106.45	59.55	83.00
August	104	48	95.87	55.35	75.61
September	108	46	98.20	53.06	75.63
October	96	38	75.87	44.90	60.38
November	82	34	68.06	43.60	55.83
December	70	28	57.93	38.25	45.09
1900—January	70	30	53.22	41.09	47.16
February	82	30	66.28	36.92	51.60
March	94	30	76.19	42.83	59.51
April	92	34	72.60	43.46	58.03
May	100	42	86.06	52.19	69.12
June	108	50	98.40	59.00	78.70
July	112	92	103.48	61.16	82.32
August	110	50	96.45	56.51	76.48
September	100	42	87.40	49.93	68.66
October	96	30	79.54	45.87	62.70
November	88	36	70.80	44 46	57.63
December	64	26	53.74	37.35	45.54
1901—January	74	22	58.25	37.67	47.90
February	76	30	63.22	41.14	52.28
March	84	28	70.58	39.74	55.16
April	86	30	76.20	39.33	57.76
May	96	42	82.12	51.09	66.61
June	112	46	99.93	54.80	74.36
July	112	50	103.61	60.31	81.96
August	110	50	99.87	62.25	81.06
September	102	44	88.86	50.06	69.46
October	100	38	85.29	49.35	67.32
November	86	32	77.06	40.20	58.63
December	78	18	69.22	30.32	49.77
1902—January	78	20	56.58	32.00	44.29
February	92	24	69.14	39.78	54.46
March	90	32	68.00	39.54	53.77
April	88	38	75.46	43.66	59.56
May	---	--	------	------	------
June	---	--	------	------	------

The highest temperature ever recorded at Tulare was 120° Fahr.; the highest recorded at the substation since 1888 was 119° (in July, 1892, and June and August, 1895). Since 1895 the thermometer has not recorded over 114° (July, 1899), but has often reached 112°. It is a dry heat, healthful, excellent for outdoor labor, and where the water supply has been sufficient, is excellent for many kinds of crops. Where surplus alkali does not interfere, the climate produces unsurpassed peaches, raisin grapes, alfalfa, etc.

FROSTS AND FROST EFFECTS.

Severe frosts are common, and in this part of the valley seriously limit the culture of some otherwise profitable crops, such as figs, olives, and oranges. All these belong to the region nearer the foothills. The lowest temperature recorded at the substation was 17° Fahr., but points in the district have a minimum record of 14°, and 20° to 22° quite often occurs. At the substation in eight successive winters, November averaged 4 frosts a year; December, 9; January, 7; February, 3; March, 3, and April, 1.

Since the last report, the number of frosts recorded was as follows:

NUMBER OF KILLING FROSTS.

	1900.	1901.	1902.	Lowest Temp.
January	1	7	17	20°
February	3	4	2	18
March	1	1	0	28
April	0	2	0	32
November	0	0	0	--
December	3	22	0	18

The number (22) of frosts in December, 1901, beats the record here, and that of January of the present year is also unusual. Such long-continued cold is very severe on plant growth, as the following notes will show:

The Carob.—Many trees which have stood fairly well here for many years past have now been greatly injured or killed outright by frosts. The last two of the carobs (*Ceratonia siliqua*), with trunks of 3 or 4 inches in diameter, were killed to the ground, but are sending up masses of sprouts from the crown. The tree is utterly unfit for this district.

Grevillea robusta.—This fine tree, which had reached a height of 25 feet and a trunk diameter of 7 or 8 inches, was badly affected, large branches being killed. Trees in the town of Tulare, in Visalia, and in Hanford also suffered. The Grevillea, or Australian fern tree, is unfit for planting in the valley.

Oranges.—Both sour and sweet stock oranges were nearly destroyed. Another such winter would compel the removal of the stumps. Young growth now starting freely requires several seasons to mature sufficiently to be again reasonably safe. Orange trees suffered in the surrounding country nearly to the foothills; Lindsay, Porterville, etc., escaped quite well. A small Kumquat, or gooseberry orange from Japan, proved hardier than the others. It was somewhat sheltered by a fig tree, but still was evidently more frost-resistant than the standards.

Camphor (*Cinnamomum camphora*).—This beautiful and valuable tree, which withstands some alkali and has hitherto grown well in the region, suffered severely. The lower 12 or 15 feet of leaves and side branches were pretty well destroyed, but new buds have now started. Cold of 18°, and 39 successive frosts in two months, December and January, were all that this tree could stand—marking the extreme limit of its endurance. The top of the tree was untouched and it will recover rapidly.

Olives.—The olive trees have nearly all suffered. The crop was of course destroyed in all cases where it remained on the trees after December 1st. The following varieties were very badly injured, the trees being practically frozen to the ground, or at least to the main stem.

Nevadillo blanco	Killed to the ground in heavy alkali soil; half killed in sandy soil.
Corregiolo	Only injured in heavy alkali.
Razzo	Badly affected everywhere.
Atrorubens	Worst in the alkali soil.
Columbella	Partially frozen on alkali soil.
Nigerina	Injured only in heavy soil.
Rubra	Injured in heavy soil; not touched on the sand.
Uvaria	Partially frozen.

The most tender of all these trees is Nevadillo blanco, which has no value here. The following varieties of olives stood the frost considerably better than the preceding list:

Amellau	Lavagnino	Mission	Piangente	Regalis.
Atroviolacea	Macrocarpa	Oblonga	Picholine (true)	Salonica
Bella de Spagna	Manzanillo	Palazzriolo	Pleureur	Tagiasco
Frantoio	Morchaio	Pendulina	Polymorpha	

Præcox has hitherto been very hardy; this year it suffered considerably. Atroviolacea also suffered some that year. On the sandy soil the following varieties were not injured: Rubra, Manzanillo, Salonica, Oblonga, Mission, and Macrocarpa.

The best olives here for hardiness prove to be the following: Macrocarpa, Manzanillo, Mission, Oblonga, Pendulina, Redding Picholine, and Salonica. Where there is little alkali and the soil is light, a few others make good trees and withstand frost fairly well, but the safer list on heavier soil includes only the seven varieties mentioned. The oldest trees near the house suffered more than in previous years, and here the Mission and Columbella were noticeably the best, and were full of bloom by May 1, 1902. Columbella is tender on the heavy alkali soil; on light and less alkaline soil it is one of the best.

African Date Palms.—These have suffered more during the last winter from frost than in any previous year. None were killed, but all, even Seevah, the hardiest, were cut back badly. This variety is the earliest bloomer; it was in flower April 1st, Amhat and other male plants being generally only in sheath then. The impossibility of natural pollination is evident. If this plantation were at Lindsay or Porterville it would grow much better and perhaps the varieties would bloom nearer together, as the more tender sorts are the ones whose growth is severely checked and which blooms late. None of the palms except Seevah bloomed in 1899 or 1900. In 1901 two male varieties bloomed.

Eucalypts.—On the south side of the station tract is a row of large eucalyptus trees. These were planted ten or twelve years ago, and many species have done very well here. Among these are *E. amygdalina*, *E. corynocalyx*, *E. rostrata*, and *E. viminalis*. The common blue gum (*E. globulus*) has often suffered from frost. This winter (1901–2) many species were severely injured, the young shoots and lesser branches

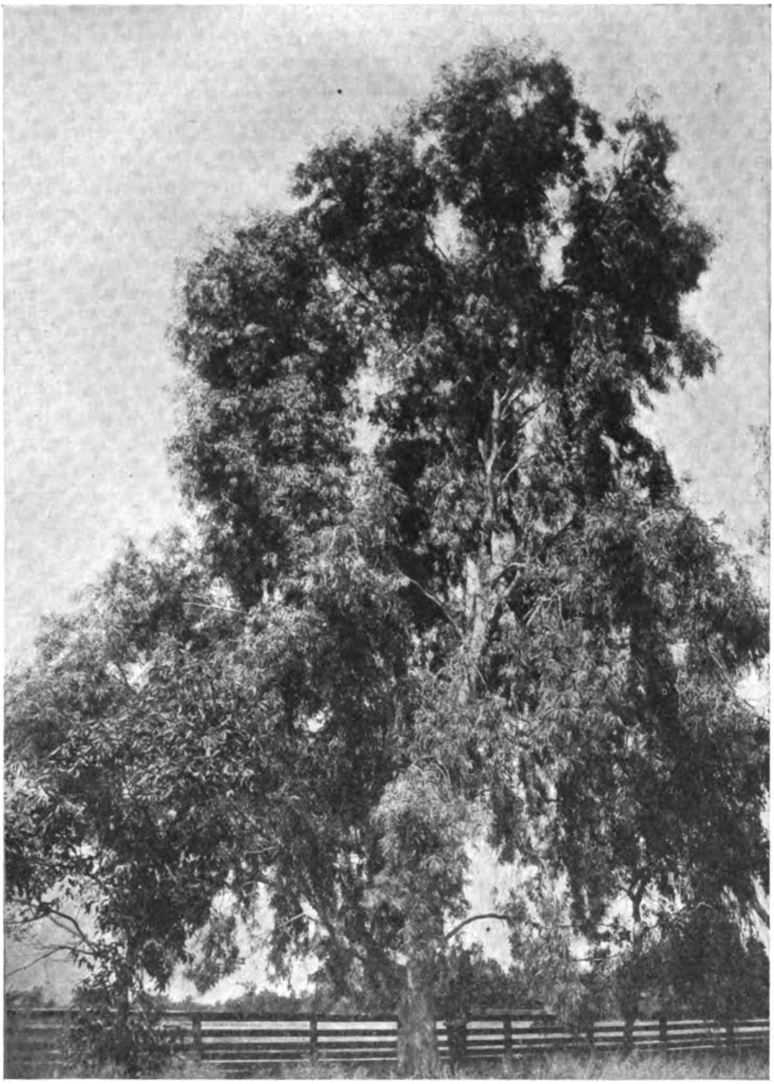


PLATE 4. EUCALYPTUS VIMINALIS ON STRONG ALKALI.

being killed. The photograph (Plate 4), which shows a large *E. viminalis* in the center, illustrates how well these eucalypts have grown on quite strong alkali soil.

In this district the best species to plant are undoubtedly *E. rostrata*, *E. viminalis*, *E. corynocalyx*, and *E. amygdalina*, all strong growers and valuable trees, with *E. globulus*, the most rapid grower, worth using only where it does not suffer from frosts. There is at Tulare City a large grove of eucalypts made by the Southern Pacific. Here some fifteen species are represented, and nearly all have done well, the more tender species being sheltered by the taller and hardier trees. *E. eugenioides*, *E. leucoxylon*, *E. robusta*, and *E. obliqua* are in this collection.

THE ORCHARD.

The substation orchard has remained about the same for the past few years, the alkali being controlled by small applications of gypsum, as elsewhere noted. The quality of some of the fruit is better than it was a few years ago, as the trees are now in these cases healthier. Experience has shown that this region is unfitted for certain lines of fruit culture, but there is undoubtedly some reaction toward more planting of suitable sorts and on good land. The substation orchard has now been maintained a long time and is very significant in its results. No other orchard now exists which was set at the same time on similar soil.

Apples.—No more apple trees have yielded to alkali, and the crops since 1896 have been of increasing quality and size. The following table shows the varieties which did best in 1901. Some of the fruit was quite small, but most of it was of fair size and some very large. The "ripening season" is notably at variance with that of the same varieties in other districts:

APPLE STATISTICS AT TULARE SUBSTATION.

Name.	Began to Ripen.	Average Weight.
Alexander	July 19	8½ oz.
Bledsoe	Aug. 22	9 "
Fameuse	Sept. 14	4½ "
Grimes' Golden	Sept. 28	7½ "
Hoover	Sept. 8	8½ "
Jonathan	Sept. 14	5 "
Keswick Codlin	Aug. 8	2½ "
Lincoln	Aug. 1	6 "
Loy	Aug. 2	7½ "
Missouri Pippin	Sept. 8	6 "
Mountain Beauty (crab)	July 12	½ "
Northern Spy	Sept. 28	5 "
Pewaukee	Sept. 28	8 "
Red Bietigheimer	July 19	12 "
Rhode Island Greening	Sept. 15	7 "
Shirley	Sept. 25	6 "
Violet	Aug. 8	12½ "
Whitney Crab	July 12	1½ "
White Astrachan	July 24	12 "
White Winter Pearmain	Sept. 28	10 "

None of the above apples are good keepers here; they do not last long after being gathered, and by November 1st even the winter sorts are practically gone. The quality of the early apples is somewhat better than that of the later sorts, which are apt to be tough and tasteless, fit only for kitchen use. In the years of lowest summer temperature the quality of the apples is better than in the hotter seasons; sometimes many of them are fairly cooked on the trees.

Pears.—The great value of this fruit in this region has before received comment. It is one of the trees best adapted to alkali soils, when not too strong. But in the past three years much blossom blight has injured crops in the district, and in 1901 there was little fruit anywhere except at the substation, where the little blight that appeared in the spring of 1902 was sprayed with copper solution.

The pears which bear best are Andre Desportes, Beurré Gifford, Beurré Gris, Beurré Clairgeau, Clapp's Favorite, Dearborn Seedling, Kennedy, Howell, Idaho, Lawson, Mt. Vernon, and White Doyenne. Bartlett has hardly had an even chance, standing as it does in stronger alkali. Seckel bears poorly, but the fruit is excellent. Many other sorts bear well some seasons. The following table gives the statistics of an average crop:

STATISTICS OF PEAR ORCHARD.

Variety.	Date When Gathered.	Average Weight.
Andre Desportes	July 14	3½ oz.
Bartlett	Aug. 8	8½ "
Beurré Gifford	July 12	4 "
Beurré Gris	Oct. 23	6½ "
Beurré d'Amanlis	Aug. 2	5 "
Beurré Lucrative	Aug. 2	4½ "
Beurré Clairgeau	Sept. 4	10 "
Beurré d'Anjou	Oct. 2	8 "
Barry	Oct. 17	3 "
Black Pear of Worcester	Oct. 2	10 "
Conseiller de la Cour	Aug. 8	10½ "
Cole	Aug. 17	12 "
Clapp's Favorite	Aug. 2	9 "
Colonel Wilder	Oct. 2	11 "
Dearborn Seedling	July 19	1½ "
Doyenne d'Eté	June 28	2½ "
Doyenne d'Alençon	Oct. 17	4½ "
Doyenne du Comice	Oct. 16	11 "
Duchesse d'Angoulême	Oct. 17	13 "
Easter Beurré	Oct. 23	16 "
Forelle	Oct. 30	1 "
Flemish Beauty	Aug. 8	9 "
Glout Morçeau	Oct. 17	4 "
Howell	Aug. 21	4½ "
Idaho	Oct. 5	24 "
Jean de Witte	Oct 23	4½ "
Keiffer	Sept. 16	11½ "
Kennedy	Sept. 16	9½ "
Le Conte	Sept. 16	11½ "
Lawrence	Oct. 6	4½ "
Mt. Vernon	Aug. 28	7¼ "
Paradise d'Automne	Sept. 16	6½ "
Pound	Oct. 30	21½ "
Seckel	Sept. 16	3½ "
Sheldon	Oct. 17	3½ "
Swan's Orange	Oct. 17	3½ "
Vicar of Winkfield	Sept. 2	8½ "
White Doyenne	Sept. 16	10 "

In the above list the small size of such varieties as Swan's Orange will be observed. The surprising size of Idaho deserves especial note. Idaho, Pound, and Easter Beurré are always of the largest size common to the variety named. Pound is, of course, merely a kitchen pear, but the other two are of good quality for table use. In fact, as long as the trees remain healthy on this alkali soil, the fruit produced is excellent, except that it is often hard at the core.

Quinces.—This fruit does not much better its previous bad report, needing more water and less summer heat. Orange quinces were gathered October 13th; average weight, 6½ ounces; quality somewhat higher in 1901 than in former years.

Almonds.—Only valuable here for firewood. This nut has now been tested fully. The trees grow well in most cases. In 1901, Bidwell's Hardshell bore well here, but the crop was destroyed in 1902. In a few sheltered locations in the town soft-shell almonds bear crops, and around Lindsay and Porterville the almond does very well. On Mr. Tuohy's place in Tulare there is a good crop this year (1902).

Apricots.—The crop here is usually poor. In fact, the tree is commercially an entire failure and has been so almost every year. There has been a light crop about one year in four. The failure is due to the light frosts and to the cold, alkali soil. The fruit is also poor and small, as the following table of the crop of 1901 will show:

APRICOT STATISTICS, 1901.

Name.	Date When Ripe.	Average Weight.
Smith's Triumph	June 10	1¼ oz.
Early Moorpark	" 14	1¼ "
Gooley	" 14	1½ "
Flickinger	" 16	1⅓ "
Royal	" 16	1¼ "
Oullin's Late	" 14	1¼ "
Hemskirke	" 19	1½ "
St. Ambroise	" 19	1⅓ "

There are some excellent apricot orchards near Visalia, Farmersville, and Hanford, but the crop is generally a failure in the Tulare district.

Nectarines.—The trees sometimes bear about as well as peaches here, but seem a little more susceptible to frost, and the fruit is not first rate. The three best varieties are Hardwicke, New White, and Stanwick. The season of ripening ranges from July 24th to August 8th. Victoria, Lord Napier, Boston, and Newington have not done well. The largest nectarines grown here average 3½ ounces each (Stanwick).

Peaches.—There have been excellent crops for the past five years. Some seventy-five varieties have been tested here during the past ten years. There seems to be no need to experiment much with the Spanish and Southern types, as the Persian peaches continue to do well. The Chinese Cling and the Honey peach are good varieties here, and most of the Southern kinds will do as well as these. Still, as trees of the Persian varieties remain healthy and bloom and leaf out in a normal way, there is no demand here for different sorts, as there is in portions of southern California.

An amended list of the best varieties here includes the following:

Clings: Seller's, Grover Cleveland, Chinese, Oldmixon.

Freestones: Alexander, Oldmixon Free, Elberta, Lovell, Morris White, Muir, Noblesse, Pickett's Late, Salway, Wheatland.

As a rule, peaches grown here are not very large, as California peaches go. The best sorts as grown at the substation without irrigation (average rainfall less than 9 inches) are, however, of good canning sizes, and the trees are well loaded, requiring two thinnings in the spring. The fruits of such peaches average from 10 to 13 inches in circumference, according to the variety. Specimens of yellow clingstones from young orchards in the district have measured 18 inches in circumference. These were mere monstrosities, a few of which were found on fifty acres of trees.

The following table shows the dates of ripening and average size of the peaches on the substation:

PEACH STATISTICS.

Name.	When Ripe.	Average Weight of One Peach.
Alexander	June 10	5 oz.
Amelia	Aug. 9	9 "
Beer's Smock	Sept. 16	7¾ "
Belle de la Croix	July 31	3 "
Belle Douay	July 24	3½ "
Blood Cling	Sept. 26	6 "
Brandywine	Aug. 18	7¾ "
Burke Cling	Aug. 5	8 "
Chair's Choice	Aug. 18	9 "
Chinese Cling	Aug. 5	7 "
Cooledge's Favorite	July 19	3 "
Crawford's Early	Aug. 1	6¼ "
Crawford's Late	Aug. 21	7½ "
Early Rose	Aug. 18	5 "
Elberta	Aug. 4	6½ "
Golden Cling	Sept. 6	9 "
Governor Briggs	July 24	4 "
Governor Garland	June 10	6 "
Grover Cleveland	Aug. 21	7 "
Hale's Early	June 30	4½ "
Henrietta Cling	Sept. 16	9½ "
Jennie Worthen	July 3	5 "
La Grange	Sept. 18	7 "
Late Admirable	Sept. 4	7½ "
Large Early York	July 19	2 "
Lemon Cling	Aug. 31	4½ "
Lovell	Aug. 26	8 "
Mary's Choice	July 24	5½ "
McKevitt's	Aug. 28	9½ "
Morris White	Aug. 14	7 "
Mountain Rose	Aug. 4	5 "
Muir	Aug. 18	6 "
Newhall	Aug. 12	7 "
Noblesse	July 26	6¼ "
Oldmixon Cling	Aug. 12	4½ "
Oldmixon Free	Aug. 4	5 "
Pansy Pabor	July 19	3 "
Picquet's Late	Sept. 16	10 "
Richmond	Aug. 3	4 "
Rivers' Early Red	June 24	4 "
Roseville Cling	Aug. 28	8 "
Salway	Sept. 25	11 "
Seller's Cling	Aug. 28	9½ "
Schumacker	Aug. 28	4 "
Stump the World	Aug. 28	9 "
Susquehanna	Aug. 9	6½ "
Thissell's Free	Sept. 2	8½ "
Ulattis	June 13	6 "
Ward's Late	Sept. 16	6 "
Waterloo	June 12	4 "
Wheatland	Aug. 4	6½ "
Wilkins' Cling	Sept. 6	9 "
Wonderful	Sept. 18	7 "
Yellow St. John	July 14	4½ "
Yellow Tuscany	July 19	6 "

Plums and Prunes.—After years of experiment here it is certain that the plum stock fails in alkali; peach stock does better, but the fruit needs a cooler summer climate, a heavier loam soil, and more water. The crop of American and European plums is often large, and some varieties are of excellent quality. Plums and prunes succeed extremely well in some portions of the district where conditions are more favorable. Among the best plums and prunes here are Bavay's Green Gage, Czar, Coe's Golden Drop, Belle de Septembre, Reine Claude, General

Hand, Lawrence, Tragedy, Columbia, Prince Englebert, Fellenberg, Quackenbos, Cherry, and Robe de Sergent. The English Damsons, which for a time did well, are now a failure. The Japanese plums usually fail to escape frost.

The following table shows the time of ripening and average size of plums here:

STATISTICS OF PLUM ORCHARD.

Name.	When Ripe.	Average Weight.
Bavay's Green Gage	Sept. 6	2 oz.
Botankio	July 25	½ "
Coe's Golden Drop	Sept. 6	......
Columbia	July 14	2½ oz
Czar	July 14	1½ "
Damas Noir	July 15	½ "
Damson	Sept. 5	½ "
Diaper Rouge	Aug. 3	1½ "
Duane's Purple	Aug. 9	1½ "
Fellenberg	July 16	1 "
General Hand	Aug. 25	2½ "
German	July 27	¾ "
Golden Prune	Aug. 3	1½ "
Green Gage	Aug. 8	1½ "
Guthrie's Green Gage	Aug. 9	1½ "
Ickworth's Imperatrice	Sept. 6	1½ "
Imperial Gage	Aug. 9	1½ "
Jefferson	Aug. 25	2 "
Judson	Sept. 25	1 "
Lucombe's Nonesuch	Aug. 8	2 "
Peach	July 14	1¼ "
Prince Englebert	Aug. 14	2 "
Prince of Wales	Sept. 4	1 "
Prune d'Agen (petite)	Sept. 6	1 "
Quackenbos	Sept. 6	2 "
Robe de Sergent	Aug. 29	1 "
St. Catherine	Sept. 26	¾ "
St. Lawrence	Sept. 6	1½ "
Tragedy	July 25	¾ "
Victoria	Sept. 6	1½ "
Yellow Gage	July 25	¾ "

The largest plums grown on the substation are Coe's Golden Drop, Quackenbos, and Peach, having average circumference of 6 inches, and General Hand, average circumference 7 inches.

Figs.—It has never been practicable to measure the fig crop. As it ripens, birds and visitors carry it off. In general terms, some varieties bear heavily every year, and a list of "best sorts" can now be offered with entire confidence. Hardiness is an important factor of success in this district. Nearer the foothills many varieties which fail here prove among the leading sorts. The frosts of 1901–2 severely injured a number of old trees. Hirtu du Japon is about the best of all the varieties grown here for table use; it is a delicious fig, a good bearer and quite hardy. Dorée Narbus is very early and a small but delicious fig. Ronde Violette Hâtive is an excellent variety, so is Brown Ischia. White Bourjassotte is a poor grower, but the fruit is first class. Du Roi is too tender for the district, and must, with reluctance, be discarded; it is strongly recommended for the foothills. Negro Larga, one of the largest and finest figs near the mountains, is also of doubtful hardiness here, although it bore well in 1901. The White Adriatic bears well every year.

The figs which, considered merely as trees, have grown best in the past fourteen years at this substation, are, named in order of value, the following: Dorée Narbus, Hirtu du Japon, Ronde Violette Hâtive, White Adriatic, Brown Ischia, Bourjassotte Grise, Col di Signora Bianca, De Constantine, Pastiliere, Brown Turkey, and Bulletin Smyrna. Some of these do not bear well; others are of poor quality. The three most valuable table sorts for the district, all things considered, are Hirtu du Japon, Ronde Violette Hâtive, and Brown Ischia, all of which are better in quality than White Adriatic.

THE VINEYARD.

The value of the vineyard here is further noted under the heading of "Alkali Reclamation." Mr. Forrer, the foreman of this substation, has furnished some valuable practical notes upon varieties and cultures here, based on years of experience. There is, he says, a remarkable revival of interest in grape culture in the San Joaquin Valley, and much inquiry is made regarding the best sorts to plant.

One of the best, if not the very best, of all the grapes grown here is, in point of bearing quality, the Tinta Val de Peñas, a fine upright grower, yielding large bunches of grapes, ripening about September 1st, and producing a good wine.

Equal in quality of wine, but a shy bearer, and less thrifty in growth, is the Lagrain, which also ripens early in September.

Grenache is well worth planting in this district and on such soil it is a thrifty, strong upright grower, and a prolific bearer.

Next to this in point of value here is Carignane, a heavy bearer and a good grower.

Alicante Bouschet is also first rate, and so is Aleatico, Mondeuse, Charbono, Cinsaut, Aramon, Crabb's Black Burgundy, and Mourastel. The latter has yielded from 1,500 to 2,000 pounds for thirty vines every year since of bearing age.

Beclan, though not a good grower, is a heavy bearer for its size. It should always be grafted upon one of the most strong-growing varieties; then its value would be much increased.

Mourisco Branco, while very thrifty, is somewhat inclined to bear poorly.

The following black Italian grapes bear well and grow well: Tadone, Bolgnino, Paga debito, Bollina, and Quigliano. They can be strongly recommended here.

The following white wine grapes do well here, growing thriftily and yielding good crops: Golden Chasselas, Burger, Folle Blanche, Peruno, Malmsey, Beba, Mantuo de Pilas, and Palomino.

Other excellent grapes here are Bakator rouge, Massana, Barbarossa, Verdal, Napoleon, and Mission. These, with the varieties previously mentioned, are altogether the best grown at this substation as regards the three points: (*a*) resistance to alkali, all being on their own roots; (*b*) heavy bearing, and (*c*) thrifty growth.

SMALL CULTURES.

The list of small cultures at any given time at this substation has been short, but the range tested during a series of years has been great. Seeds sent by the Department of Agriculture are spoken of under the numbers in the Inventory as well as by species. Previous reports and bulletins have from time to time given results with many different plants in alkali soils.

Plant growth here comes naturally under several heads, such as the following: (*a*) Drought-enduring plants, which yield to alkali of greater or less intensity;

(*b*) Plants which need more water than the natural rainfalls, and also suffer from alkali;

(*c*) Plants which need more water, but withstand large amounts of alkali;

(*d*) Plants which withstand severe drought and also a high amount of alkali.

Severe winter frosts still further increase the difficulties of plant life and reduce the number of "all around successes."

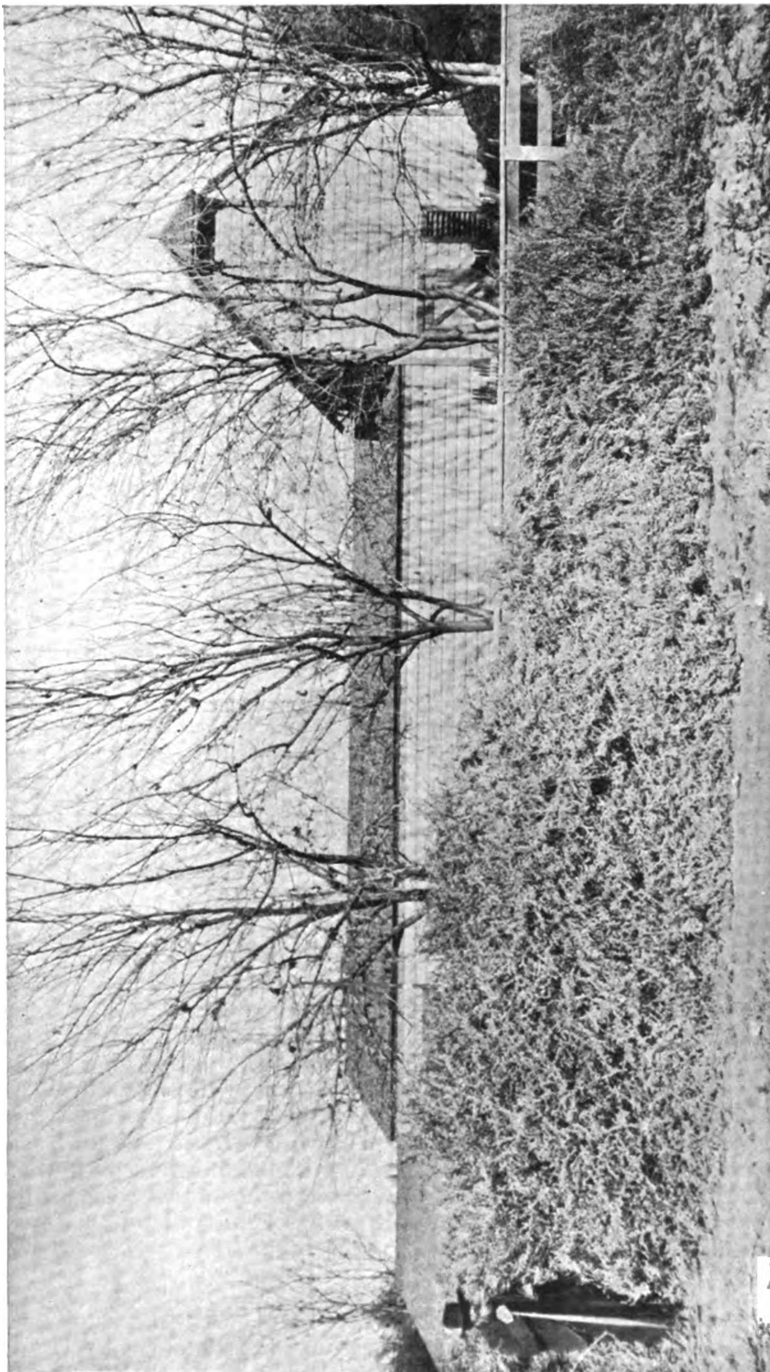
The Saltbushes.—It remains true here and at many other points in the San Joaquin where thorough tests have been made, that the atriplexes, rhagodias, and other saltbushes are of great economic importance. This has been so fully stated in previous publications, such as Bulletin No. 125, and elsewhere in this and in the previous report, that an extended paper is not now needed.

The opinion of the late Professor John A. Myers, for a long time Director of the West Virginia Experiment Station and for a number of years the American director of the work of the Nitrate Propaganda, may justly be quoted here. Under date of December 5, 1900, this able and careful man wrote from New York as follows, to Mr. W. C. Clark of San Bernardino. Professor Myers said: "I have no connection with the University of California, but I have been exceedingly interested in their experiments with Australian saltbush (*Atriplex semibaccata*). The work of the California experiment station in introducing and developing this plant for the use of the farmers of California is worth more to the State than the entire experiment station has cost since its beginning or will cost for the next fifty years."

As Professor Myers several times visited the substations, took notes upon the yield of saltbush forage, and was familiar with the analyses made here and elsewhere, his testimony is especially valuable. At that time, however, the tall rhagodia and still taller Argentine atriplexes had not been established at Tulare, and hence the trailing *A. semibaccata* was the leading species which he observed. It is still very important, but as many locations require a taller and more bush-like plant, the new *A. pamparum* in particular deserves wide testing.

As shown in the photograph (Plate 5), *A. pamparum* and *A. cachiyuyum* (which is quite similar) are very tall, strong plants, withstanding alkali in which grapevines have failed. If cut back as often as necessary, these new species make an enormous growth of fresh, soft forage, which has, by analysis, as high a food value as *A. semibaccata*. A large crop of seed was gathered in the winter of 1901–2, and experiment on a larger scale is now easy. But these Argentine atriplexes can also be grown from cuttings. Cut back in January, the stocks make new shoots twenty inches high, fit for forage in three or four months. This indicates, where there is sufficient water, at least three or four crops a year. The growth in warm weather will be much more rapid than in January–April.

The half-tall, shrubby atriplexes, such as *vesicaria* and *halimoides*, which several years ago seemed so entirely at home here, when last



Atriplex pamparum. Atriplex cachiyuyum.
PLATE 5. SALTBUSHES AT SAN JOAQUIN VALLEY SUBSTATION.

observed (May, 1902) were evidently failing and disappearing, under fair average conditions. They seldom reproduce from self-sown seeds and *A. semibaccata* easily "runs them out" and usurps the soil under field conditions. *A. leptocarpa* also yields to *A. semibaccata* in the field. In cultivated or hoed rows, *A. semibaccata* makes nearly three times as much fodder per plant or per acre as does *A. leptocarpa*, and the quality is about the same. *A. semibaccata* greatly surpasses *vesicaria* and *halimoides* in actual yield per acre. The saltbushes which are much better in points of growth and yield at Tulare than at the Central Station or at Paso Robles, are named in order of improvement: *A. semibaccata, A. pamparum, Rhagodia spinescens inermis.* All the saltbushes withstand much drought and alkali.

Turkestan Alfalfa.—Among the alfalfas growing here are plots of "common California alfalfa," of "German Lucerne," a very compact and large-leaved stock, and of Turkestan alfalfa, sent out by the Department of Agriculture (Nos. 1150, 1151, and 1159—*Medicago sativa* var. *turkestanica*). Little difference was noted among these varieties.

Three years' experience shows that while no alfalfa will withstand the droughts here and yield any summer forage, the roots of the *turkestanica* will live through the summer and give early winter feed. To some extent this is true of all unirrigated alfalfa in the San Joaquin, but the ravages of the gophers make its growth under such conditions useless. By June all the alfalfas, unless irrigated, cease growth and run to seed or die down to the roots. *Turkestanica*, like the other varieties, now receives irrigation. But the growth of the *turkestanica* is noticeably more compact than that of the common form; it has a larger leaf, more foliage, and shorter joints, hence it is an acquisition of considerable value. The alfalfas withstand considerable alkali when once a stand has been obtained, but need irrigation in this district.

Horse-Beans.—A number of forms of *Vicia faba* from different sources have been tried here for four years, in the hope that they would withstand the frost and make a good growth before the dry weather. As a rule, they have failed to mature seed, and have amounted to nothing. This applies to all the best European broad-bean varieties. A somewhat better result was obtained in the case of Nos. 7024 and 7035 of the Department of Agriculture.

No. 7024, "the Laidi horse-bean of Egypt," sown March 1, 1902, on medium but sandy alkali soil, proved to be very early. Plants were one foot high and had pods well set on May 1st. This variety is fully a month earlier than any other kind tested here.

No. 7035, sown at the same time, was beginning to blossom May 1st. A few plants were sixteen inches high, but the average was one foot.

The above tests were only partial, as these varieties should be sown with the early winter rains. Then if they withstand the cold and grow well, they will be an acquisition. But the seed was not received until the end of February. These two varieties justify field trials on better and less frosty soil.

The Vetches.—The best vetch here is the common bitter vetch (*Lathyrus sativus*), which has been tested for several years. At times, sown early and with favorable rains, it reaches a height of nearly one foot. Usually, however, as with No. 7639, sown March 4, 1902, on sandy alkali soil, it blossoms when six inches high, and spreads very little. May 1st this plot was in full bloom. It will hardly ripen seed without irrigation, nor has it ever done so here, in ten years' experience. It is not suited to the soil and climate. Even with copious irrigation it hardly yields half a ton of hay to the acre.

Lathyrus tingitanus (No. 7637 of the Inventory), grown here from several sources at different seasons, does not endure the drought. It spreads three or four inches, and ceases growth by the middle of May or early in June.

Vicia villosa has been fully tested in plots and sown with rye. Its height ranges, according to the season, from two to four inches at time of blossoming. None of the entire list of vetches has succeeded here in four seasons of growth on this sandy, alkali soil.

In the spring of 1901, *V. narbonensis* (No. 7532) and *V. ochrus* (No. 7534) were given a careful trial. They were in blossom at the height of two or three inches, May 1st. Growth soon ceased and they died by June 1st. Vicias Nos. 1504, 1506, 1507, 1509, and 1514 were grown in 1899 and 1900, but were failures.

The Lentils.—*Ervum monanthus* (No. 7522), *Ervum lens* (No. 5419), *Ervum hirsutum* (No. 5418), and various forms of the common lentil all prove unsuited to the soil. Without irrigation they seldom reach bloom, and are hardly more than two or three inches high, even with irrigation. They are affected by a small amount of alkali and fail to mature seeds.

Garbanzos.—Under various forms this notable pea, *Cicer arietinum*, has had thorough tests. In recent years much local inquiry has been made about chick peas, Colorado peas, etc., and the hope has been expressed by various newspapers that this plant would be very useful here. The same thing has been said of the vetches and many other plants long ago grown and reported upon. The utmost growth that Garbanzos makes here, when sown early, is one foot, with a few branches. As a rule, its growth is but six or eight inches; it blossoms in May, and dries up, if unirrigated, by the middle of June. Nos. 7017 and 7021 of the Inventory, sown in the spring of 1902, made the above average growth. About half of the plants were killed or dwarfed by alkali.

Lupins.—Previous reports have contained much about lupins here. Their value is very doubtful, except on better soil and nearer the mountains, where native species do unusually well. Sown early at the substation they have sometimes made quite a growth, but very cold weather checks this. *Lupinus termis* (No. 7022 of the Inventory), sown March 1st, was approaching bloom May 1st (seed received late). It made only about one fourth as much growth as did the "Palermo White." The latter, which on May 1st averaged a foot high and was past full bloom, seems to promise value here (sown March 1st).

Cereals.—The growth of the gluten wheats continues here, and seed is usually sown in December. At present the plots include Fultz (No. 5493), Golden Chaff (No. 5486), and Theiss (No. 3823), with various removes from the original. Seed from each plot is sent to the Division of Chemistry at Washington, and the changes in the grain are noted. Bulletin No. 3 of the Bureau of Plant Industry contains a great deal on the subject of the hard wheats, and other portions of this report note the work being done at substations where the development of starch is less rapid than at Tulare. The plants strengthen and tiller more with each remove from the original.

The barleys, ryes, and spelts have usually succeeded well here. No. 7531, rye, received and sown as late as March 1st, was in excellent condition on June 1st in sandy alkali, but early winter sowing is much better. No. 4281, the East Tennessee Giant Wheat, also sown late, has done fairly well here, considering the season.

Goat's Rue (No. 1456 of the Inventory), *Galega officinalis*, has been given a thorough trial. It stands drought quite well, but is not tolerant of alkali. Plants are six or eight inches high by August. With irrigation three cuttings can be made, but alfalfa is better in that case.

Sainfoin and Sulla.—Both these well-known plants, which have been grown here for ten years, resist considerable alkali. They need water in dry years if any yield be desired after July.

Millets.—Many millets have been grown here. One of the best varieties of *Panicum miliaceum* was No. 1387 from Turkestan, which resisted drought well in 1899 and 1900, and stood alkali better than wheat did on both heavy and light soils. This millet makes an excellent hay, and should prove profitable for this or for chicken feed. It is far superior to the common German Golden and other older varieties tested here.

Medicago arborea (Inventory No. 1896).—This shrubby legume, the Tree Medic, has been tested a good deal here and elsewhere. It would have considerable value if gophers would let it alone. They even prefer it to alfalfa. It stands much drought and considerable alkali.

Foxtail Furze (Inventory No. 1446).—This form of the well-known Scotch gorse has now been grown here for three years. It is a remarkable plant in its resistance to drought and alkali, and yet is extremely sensitive to the latter as soon as its limits are reached, the leaves and young shoots turning yellow very rapidly. Sheep and cattle will not eat the branches, which are nearly as thorny as the common gorse, unless crushed between rollers.

Grasses, Clovers, Etc.—For the past four years about twenty-five species of grasses and clovers have been grown here, with the aid, in most cases, of some irrigation. Perennial Rye-grass is one of the best kinds ever tested. Named in order of resistance to drought and alkali, the grasses of next importance to this are Smooth Brome (*Bromus inermis*), Italian Rye, and Texas Blue (*Poa arachnifera*).

There are few more resistant plants of any value for forage than *Melilotus alba* (Bokhara clover). Started early, it needs no irrigation and has kept green in the driest seasons (less than four inches of rainfall in the year). This is the plant that is often thought one of the worst of weeds, especially in alfalfa fields, but it is a honey-producer, and range stock will eat it.

Artichokes.—The European artichoke (*Cynara scolymus*) has been tested here for several years on strong, heavy, alkali soil. Nos. 4345 to 4350 of the Department of Agriculture, as well as seeds from other stock, were sown, and the results show that this plant grows about as well in strong alkali as does *Atriplex semibaccata*, and a great deal better than do Russian sunflowers.

Squashes and Melons.—A collection of squashes and melons was planted in 1901, on sandy alkali soil about as good as any on the substation. The plants, though making a start, suffered much. A few watermelons ripened in October, but were very poor in quality. All the vines were watered every evening, and were mulched. Some vines were watered by means of a sunk box into which water was poured. It seemed impossible to keep the melon vines growing well. The summer squashes did a little better. The Tsama or Khama stock-melon throve very much better than any other cucurbit, and were hardier, but even these suffered in amount of crop from alkali.

SOUTHERN CALIFORNIA SUBSTATION.

(In Chino Valley, reached from Pomona, Ontario, or Chino. Elevation of main tract, 856 feet; of moist-land tract, 800 feet.)

The substation work in the Chino Valley is being carried on at two points: (1) on a thirty-acre tract three miles southeast from Pomona (or about the same distance southwest from Ontario); and (2) on a ten-acre tract about two miles south of the thirty acres, and about a mile from Chino. The thirty-acre, or home tract consists chiefly of reddish mesa soil suitable for citrus fruits; about one fifth is gray gravelly soil from the wash of the Sierra Madre. The ten-acre tract consists of the characteristic dark loam so common in the lowlands of the valleys and along the coast.

Brief History of the Substation.—This substation was established in November, 1890. There was then an abundant supply of free water, delivered by gravity from the main reservoirs, supplied chiefly by flowing artesian wells. The average rainfall was then greater than it has been in recent years, and the winter floods even swept across a large part of the home tract (1890–91), enriching the soil. Since then the settlement of the valley and the development of great water systems have compelled resort to pumping not only at the substation, but generally throughout the district. The value of water has steadily increased, and its economical use has here become one of the leading agricultural problems.

When the station was founded, in 1890, the young orchards of the district were much more diversified than now. Nearly all kinds of deciduous fruits which prosper in northern or central California were planted by the land-owners and were doing well. Almonds, peaches, apricots, and prunes, as well as apples and pears, were being planted. Olives were considered more promising than anything else, and walnuts were thought desirable on the heavier soils. Citrus fruits were chiefly planted on highlands of the rim of the valley, east and north. The especial demands made upon the substation were for more knowledge of all kinds of fruit culture, particularly deciduous; also for information about sugar-beets, for drainage and reclamation of moist lands, such as the ten-acre tract, and, as one newcomer expressed it, "for whatever can be found out about the soil, climate, and productiveness of the Chino Valley, as few of us know anything at all about any part of California." Along these lines, to fulfill the demands of the community, the substation developed. While experimenting with all kinds of deciduous fruits on a large scale, citrus fruits, olives, figs, and other semi-tropic fruits received no less attention. The substation also bore its share in the rise of the great sugar-beet industry of the valley, testing many varieties, distributing seeds, and examining other beet lands. Its numerous other activities can hardly be stated in a paragraph; their record runs through previous reports.

From its establishment, this substation has been popular in the community, and the foreman has been in demand over a large extent of country, as horticultural expert and local adviser. The number of real farmers, fruit-growers, gardeners, nurserymen, etc., who visit this substation is far in excess of the number visiting any other substation of the system, as the horticultural population is dense, and the place is very accessible. There have been many meetings of farmers' clubs here; farmers' institutes have been held at the substation; the local newspapers frequently send reporters out to see what is going on, and the influence of the substation seems to be increasing in all directions. Its location was fortunate in many respects. Though a purely citrus station might well have been further inland, the problem of choosing one point between Los Angeles and the desert where experiments could be carried on for the widest possible area was admirably solved by selecting the Chino Valley, which is adapted to the culture of a vast range of species of plants.

There has been but one change in the foremanship here since 1890, and this is one of the especially fortunate items in the history of the substation. Mr. McLennan, sent there in November, 1890, was superseded in 1893 by Mr. J. W. Mills, a former student at Berkeley, who is therefore the second-oldest foreman, in point of service, being surpassed only by Mr. Forrer, of the Tulare substation. Mr. Mills has been over a large part of southern California at farmers' institutes and otherwise, and is becoming a well-posted person upon practical topics of agriculture. He has been helped, during his entire service, by successive patrons of unusual agricultural knowledge—Mr. Gird, then owner of the Chino Ranch, Rev. C. F. Loup, and Hon. S. N. Androus; also by a large number of local specialists in olives, oranges, beets, and other crops of the region.

CLIMATE.

The climate of the Chino Valley has a well-deserved fame in southern California. There is not much difference, either in temperature or rainfall, between Chino, Ontario, and Pomona, the three leading towns of the valley, nor is the climate of these places much different from that of Riverside, Colton, and San Bernardino, farther inland, in another valley system, excepting as regards rainfall. In this respect the Chino region in normal seasons is less favored than the coast, and more favored than districts farther inland. The following table shows some comparative rainfalls at various places east, west, and near the substation:

Place.	1892–3.	1894–5.
Los Angeles	22.00 inches.	23.00 inches.
Pomona	20.97 "	20.43 "
Ontario	21.00 "	20.24 "
Chino	20.19 "	20.00 "
San Bernardino	20.29 "	14.85 "
Redlands	15.20 "	17.75 "
Riverside	15.06 "	11.65 "

At the substation, situated about equidistant between Pomona, Ontario, and Chino, the rainfall in 1892–3 was 19 inches, or less than at either point; while in 1894–5 it was 22.96 inches, or more than at these places, and nearly as much as at Los Angeles.

The rainfall at Los Angeles, according to the records of the Southern Pacific Railroad, the Weather Bureau reports, and other available records from 1892 to 1902, averaged 16.85 inches; that of San Bernardino for a slightly longer period averaged 14.94 inches. The average for the Chino Valley lies between these two, or about 15.50 inches, while that of

Riverside and Redlands falls below San Bernardino. There have been "wet years," such as that of 1883-4 (rainfall at Los Angeles, 38.22 inches), and "dry years," such as 1876-7 (rainfall at Los Angeles, 5.28 inches). Only the establishment of enormous systems of irrigation, supplementing the annual rainfall, has enabled these thriving communities to carry on such intensive horticulture.

At the substation the rainfall has been as follows:

Season.	Rainfall, in Inches.	Season.	Rainfall, in Inches.
1889-90 (mean of surounding towns)	22.25	1895-96	8.75
		1896-97	16.99
1890-91	12.55	1897-98	9.39
1891-92	14.32	1898-99	5.71
1892-93	20.72	1899-00	9.58
1893-94	11.18	1900-01	17.74
1894-95	23.00	1901-02 (to April)	11.41

The average annual rainfall for thirteen years has been a little more than 14 inches. The average of the four years, 1889-93, was 17.46 inches, but the average of the four years, 1895-99, was only 10.20 inches. As at Paso Robles and Tulare substations, the rainfall of the years immediately following establishment here was more favorable than the average of a longer period.

The climatic record of the substation since the issuance of the last report, which closed with June, 1899, is shown in the following table, which includes temperature, rainfall, and weather by months:

	Mean Temperature of Month	Maximum Temperature of Month	Minimum Temperature of Month	Greatest Daily Variation	Least Daily Variation	Rainfall During Month	Number of Clear Days	Number of Fair Days	Number of Days when Rain Fell	Number of Cloudy Days
1899—July	75.3°	102°	51°	47°	31°	.00	26	5	0	0
August	72.5	102	47	48	23	.00	22	9	0	0
September	75.7	106	49	48	21	.00	21	8	0	1
October	62.7	95	38	40	9	1.92	14	11	6	6
November	59.0	85	38	40	5	1.39	14	12	3	3
December	54.2	80	32	39	7	.95	14	11	3	6
1900—January	58.2	80	34	37	5	1.30	17	9	2	5
February	57.3	87	34	45	15	.05	9	17	1	2
March	61.7	93	39	46	14	1.02	8	19	2	4
April	57.9	86	35	43	7	.95	12	5	5	13
May	66.2	96	40	45	12	2.00	21	5	4	5
June	68.8	96	45	49	13	.00	13	16	0	1
For the year	64.9	92.3	40.1	43.9	13.5	9.58	191	127	26	46
1900—July	72.3	99	48	43	21	.00	18	12	0	1
August	70.5	107	46	46	21	.00	12	19	0	0
September	66.4	97	44	49	20	.00	17	12	0	1
October	63.8	96	38	48	15	.34	14	15	2	2
November	61.6	93	38	47	8	8.38	22	2	6	6
December	54.7	80	27	38	22	.00	19	11	0	1
1901—January	51.0	76	23	38	10	2.89	7	12	10	12
February	55.5	92	28	41	8	4.46	14	6	8	8
March	57.5	90	33	48	16	.48	24	7	1	0
April	59.5	85	33	43	10	.19	18	10	2	2
May	64.3	86	43	34	13	1.00	7	21	3	3
June	71.4	108	46	53	17	.00	11	18	0	1
For the year	62.4	94.4	37.2	52.9	15	17.74	183	145	32	37

	Mean Temperature of Month	Maximum Temperature of Month	Minimum Temperature of Month	Greatest Daily Variation	Least Daily Variation	Rainfall During Month	Number of Clear Days	Number of Fair Days	Number of Days when Rain Fell	Number of Cloudy Days
1901—July	76.7	104	50	51	28	.00	21	9	0	1
August	80.6	109	49	48	28	.00	18	13	0	0
September	68.1	92	44	45	18	.00	30	0	0	0
October	66.0	96	43	48	20	2.29	22	4	5	4
November	59.0	84	37	37	15	.00	15	13	2	2
December	54.2	83	24	42	15	.00	0	0	0	0
1902—January	53.0	86	28	43	15	1.92	19	7	4	5
February	54.0	81	30	37	11	3.35	16	5	6	7
March	55.5	84	31	41	16	3.85	9	12	7	10
April										
May										
June										

IRRIGATION.

The amounts of water used to produce crops in the Chino Valley are, as a rule, extremely small. Waste has been reduced year after year, owing to the high cost of water and consequent improved methods. The deep-furrow system, followed by cultivation, is now practiced.

Amounts of Water Used.—Between January and the end of June, 1898, the orchard received 2,880,000 gallons of water; between June, 1898, and January, 1899, it received 3,710,000 gallons. This total of 6,590,000 gallons applied in practically fifteen months (since no water was artificially applied in October, November, and December, 1897) was distributed as follows, arranged in order of greatest use:

	Gallons.
Citrus fruits	800,000
Peaches	790,000
Grapes	770,000
Plums	730,000
Lawn, garden, nursery, etc.	687,000
Pears	625,000
Apples	500,000
Olives	490,000
Figs	350,000
Alfalfa	285,000
Forest trees	270,000
European lupins	190,000
Cherries	125,000
Almonds and apricots	78,000

Since the rainfall of this region between September, 1897, and April, 1899, eighteen months, covering the entire period during which this irrigation was used, was only 15.10 inches, and since the area to which it was applied was about twenty acres, the average of irrigation and rainfall (7.48 gallons equaling one cubic foot of water) was a trifle over 25 inches. The amount of water, of course, varied greatly in regard to different crops. The olives received in rainfall and irrigation but 22.70 inches, while the oranges had nearly 29 inches.

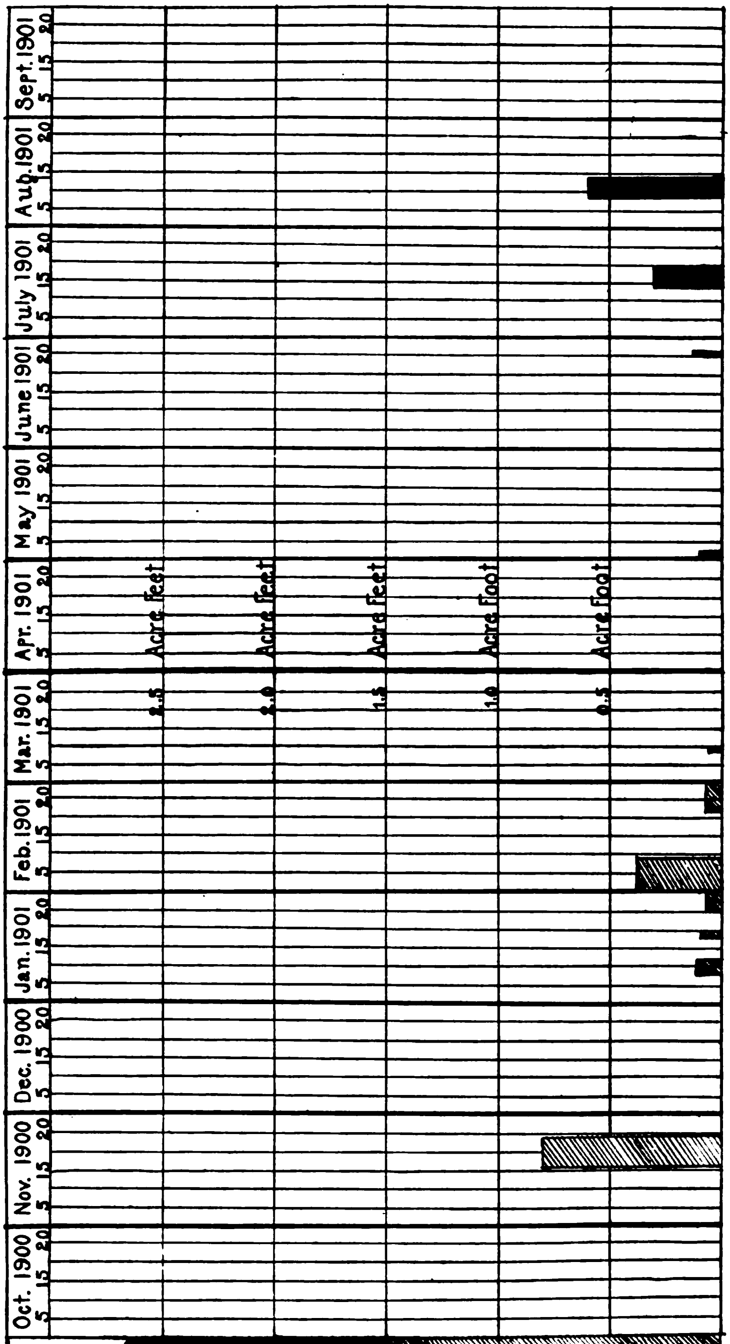


PLATE 6. DIAGRAM SHOWING IRRIGATION OF ORANGE TREES IN DEEP FURROWS.
Solid areas represent depth of irrigation; shaded, rainfall.

In the summer of 1900 the total amount of water used was 3,213,000 gallons on twenty acres, equal to about five inches of rainfall. The citrus trees received about three tenths of the entire amount of water used.

Irrigation in 1901.—During the season of 1901 the rainfall was greater than for two previous years, and the amount of water applied was also in some cases larger, as it was evidently needed by the trees. Experiments were made in the use of shallow and deep furrows. Records were kept in acre-feet and decimals thereof. The rainfall was nearly 17 inches, equal to 1.48 acre-feet.

Deep versus Shallow Furrow Systems.—The orange grove was divided into two portions, each irrigated by a different method. That portion on which the shallow-furrow system was applied required 1.167 acre-feet of irrigation (one extra irrigation), while the trees watered by the deep-furrow system required but 1.02 acre-feet. These points, with the dates and amounts of water given, are shown on the accompanying charts (see Plate 6, page 66).

The results of these experiments with deep and shallow furrows were interesting and valuable, justifying more complete discussion here. The first irrigation given to the grove was in the first week in July. The two east rows were irrigated from that time and through the whole of the season, in furrows twelve inches deep, while the three west rows were similarly irrigated, except that the depth of the furrows was but five inches. The soil had been deeply plowed twice during the six months previous and was in excellent condition.

How to Plow Furrows for Irrigation.—The methods of plowing furrows in an orchard are numerous, and many of them entail a large amount of extra labor in shoveling earth out of the intersecting points. The accompanying diagram will show the proper way in which to plow irrigation furrows, whether deep or shallow (see Plate 7, page 68).

In this diagram the surface is supposed to be graded so as to slope from north to south, and the water is to be applied on all sides to each tree, at the outer circle of branches, in the most economical manner. Therefore, first plow the furrows passing through *b* and *c*, running north and south. Next plow all the cross-furrows running east and west; then return and plow all the main water channels running north and south across the orchard. Two of them go down the center between the rows, and two more run close to the trees. The furrows will need some digging at the points *a*, *b*, *c*, and *d*, so as to have the water follow the trees (*a b c d*). The water is not allowed to run through the interrupted portions of the furrows shown by the dotted lines.

Absorption and Penetration of Water.—Mr. Mills reported as follows in regard to the application of water in these furrows: "After the water was once run to the end of all the furrows there seemed to be no difference in the amount of water taken in by the soil in the two sets of furrows. The water was longer in first reaching the lower ends of the deep furrows than it was in reaching the lower ends of the shallow ones. This seemed to be due to the soft soil rolling back into the deep furrows, which impeded the flow of water; but after this loose soil was once wet there was apparently no difference in size of the streams required to reach the lower ends of the two sets of furrows. The entire orchard was irrigated at once; that is, the water was turned on all of the trees at the same time and kept running for the same length of time on them all until the irrigation was completed for each time, except, of course, in the case of the extra irrigation in June."

The absorbing capacity of the two systems of furrrows, deep and shallow, appeared to be about the same, but there was a very noticeable difference in the losses by evaporation. At one time, when water was running for eighty-four hours in all the furrows, the surface between shallow furrows became saturated. As soon as possible this surface was cultivated, but for days afterward it showed moisture every morning (an

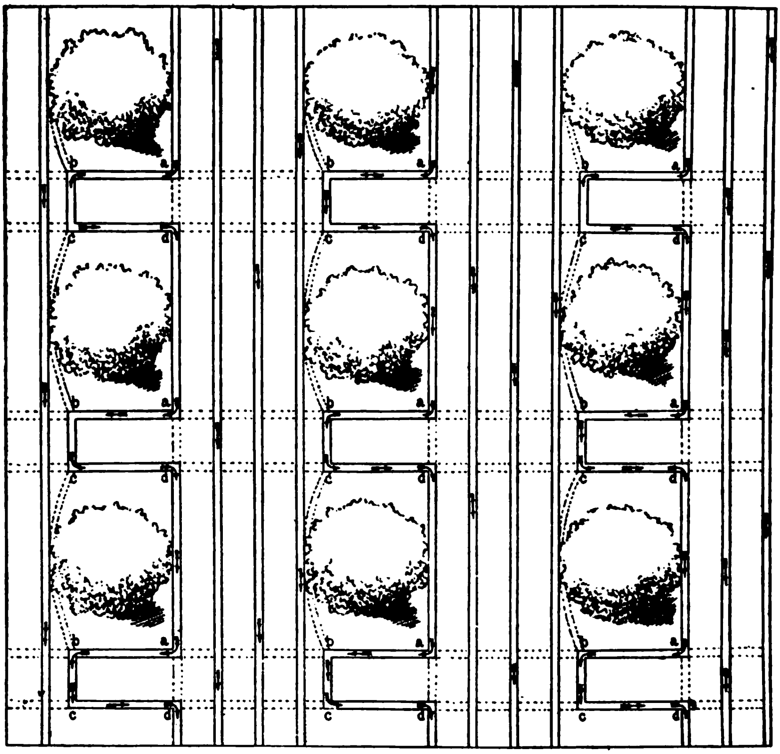


PLATE 7. How to Plow Furrows for Irrigation.

evidence of waste). In the case of the deep furrows, the surface soil showed moisture only near the head of the ditch, at the upper end of the rows, and immediately over the furrows, which of course had been filled as soon as practicable, as was also done with the shallow furrows. The moisture thus saved for the use of the roots by deep-furrow irrigation was sufficient to carry the trees from the first week in May until late in July. On the other hand, the loss by evaporation from shallow furrows compelled the foreman to give an extra irrigation in June. In other words, the trees irrigated by deep furrows went twenty days longer, thus saving cost of extra water and labor, besides keeping in better condition.

The penetration of the water sideways and downwards in the two methods used is very clearly shown by a diagram made by Mr. J. W. Mills, and used in his Bulletin No. 138, on Citrus Fruits. This exhibits cross-sections on the deep and shallow furrows, at different periods of time after the water was applied:

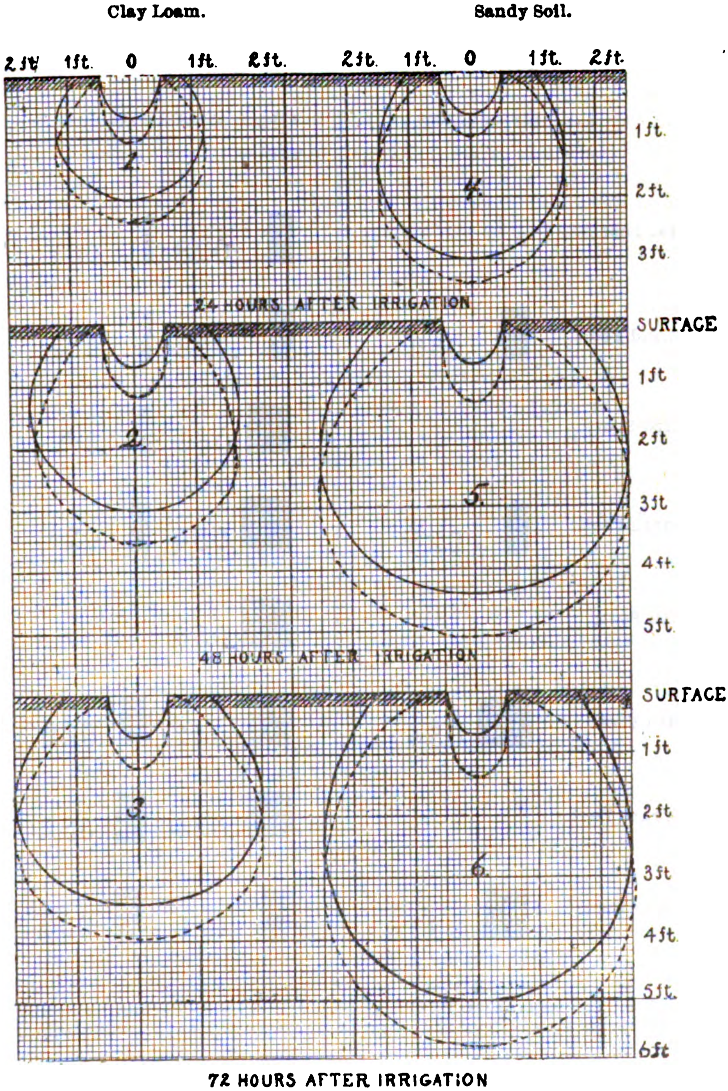


PLATE 8. PERCOLATION EXPERIMENTS. SPREAD OF WATER FROM DEEP FURROWS IN HEAVY AND LIGHT SOILS.

The soil in and between the furrows was probed daily during these experiments. The spread of water was very slow. Even at the end of two weeks after irrigation the moisture lacked three feet of meeting in the wider spaces (13 feet) between the main furrows next to the trees.

Water applied to this strip close to the trunks of the trees would have been to a large extent wasted, and one aim of this experiment was to avoid waste as much as possible.

On the sandy-loam soil of the substation, the irrigation furrows should not be more than four feet apart; on the lighter sandy soil they are better if only three feet apart. The former soil does best with a "run" of seventy-two hours, and the latter with forty-eight hours, these periods saturating the soil five feet deep, which proved ample for citrus fruits, olives, etc.

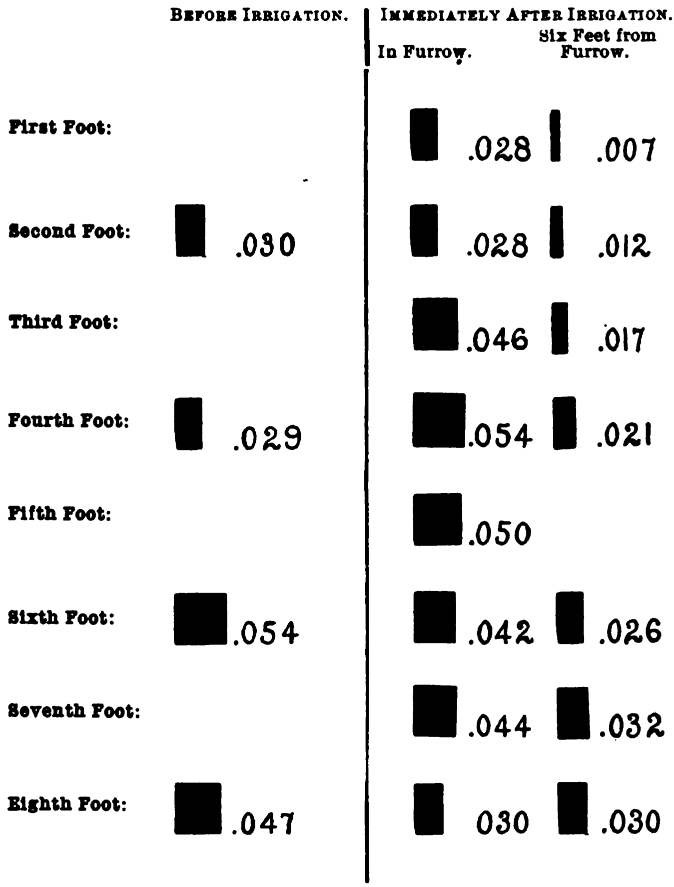


PLATE 9. Percentage of Water in Soil at Different Depths Before the Irrigation Season, and Immediately After Last Heavy Irrigation.

Weather during Irrigation.—The weather during the irrigation season was very warm. During the last week in June and the first week in July the daily maximums ranged from 90° to 108° Fahr. In fact, during the forty-five days after June 25th, the thermometer registered from 90° to 100° for twenty-nine days and from 100° to 108° for fifteen days. During this "hot spell," the longest recorded at the substation for ten years, the orange trees irrigated on the deep-furrow system did not suffer, but those irrigated by shallow furrows, as above noted, began to suffer and were given an extra supply of water in June. The irrigation of August 9th, which the entire grove received, carried all the trees along for forty days, when those on the shallow furrows showed signs of distress. A shower of rain (0.45 of an inch), followed by a heavy rain (1.87 inches) a week later, ended the irrigation season.

Amount of Water in the Soil.—Determinations of the percentage of water in the soil at different depths before the irrigation season began and after the last and heaviest irrigation were made. The accompanying diagram (Plate 9) shows results. The first fifteen determinations—those in irrigation furrows—were made five days after the end of the irrigation of August 19, 1901, or eight and a half days after the water was turned into the head ditch. The last four determinations were made on May 1, 1901, just before the first irrigation of the season.

THE ORCHARD.

After six years of trial, it has become necessary to discard a large number of varieties of deciduous fruits grown at this substation, and they are being replaced with kinds which it is thought will prove better suited to this region. A bulletin upon deciduous fruit culture in the Chino Valley will probably be prepared at some future time, setting forth in detail the results of this extended experiment. The following brief notes show some of the observations already made here.

Apples.—In spite of irrigation when needful, frequent spraying, and, in brief, the most careful treatment, the greater portion of the varieties planted here are dead or dying, show blight, are non-productive, or, if bearing, have fruit of poor quality. The district is evidently unsuited to this tree.

The following varieties are badly affected with blight: Alexander, Arabskoe, Duchess of Oldenburg, Everbearing, Keswick Codlin, Mammoth Black, Marshall Seedling (Red Bellflower), McMahon White, Pewaukee, Perry Russet, Sweet Bough, Wealthy.

The following varieties are non-productive, or only yield fruit that is extremely poor (though in favorable locations these are excellent varieties); some of these also appear in the above list of blight-infected sorts: Amassia, Belle de Boskoop, Calvert, Duchess of Devonshire, Fameuse, Lady Lankford, Mammoth Black, Montreal Crab, Marshall Seedling, Nero, Perry Russet, Sweet Bough, Reinette de Caux, Red Bietigheimer, Twenty Ounce, Walbridge, and Yellow Siberian Crab.

Six varieties of apples appear to be absolutely blight proof, and are as far recommended for general planting as any can be in this district. These varieties are Early Ripe, Jonathan, Skinner's Seedling, Smith Cider, Rhode Island, and White Astrachan. Gravenstein is slightly affected with blight, but not seriously. Sonoma is a strong grower and a good bearer.

Other varieties which are worth further trial are Arkansas Black, Hoover, Lawver, Ortley, Red Astrachan, Shannon, Stump, White Winter Pearmain, Yellow Newtown Pippin, and York Imperial. A number of the newer Russian varieties have been planted, but are not yet in bearing. Many of the crabs have done poorly and some of the older Russian varieties, but the list of useful sorts includes several, such as the Astrachans, that are Russian. About a hundred varieties have been tested first and last in this apple orchard.

Pears.—A very fine collection of pears was established here, and it included all the leading varieties, European and American. Many are now dead or dying, and in no case where two trees of a kind were planted have both done well. Beurré Clairgeau, Cole, Chinese Sugar, Duchesse d'Angoulême, Epine Dumas, Madam Loriel de Barney, Madeleine, P. Barry, and St. André, nine varieties in all, are retained, the last named, however, being of poor quality. These now seem reasonably free from blight and bear reasonably well, though trees of Beurré Clairgeau, Madeleine, Madame Loriel de Barney, and St. Andre have died from blight. In the cases, also, of Frederick Clapp, Clapp's Favorite, and Winter Nelis, one or two trees of each variety died from this disease. It may be said, therefore, that only Cole, Chinese Sugar, Duchesse d'Angoulême, and Epine Dumas have proved immune. Le Conte and Idaho certainly have not. The following varieties yielded to blight (two, and in several cases, three of each sort): Anne Ogereau, Augustin Daly, Bartlett, Baronne de Mello, Beurré Gris d'Hiver, Beurré Golden of Bilbao, Beurré Bosc, Bonne du Puits Ansaults, Brockworth Park, Court Queen d'Automne, De Tongres, Directeur Alphand, Duchesse de Mouchy, Exeter, Easter Beurré, Eugene Appert, Glout Morçeau, Gray Doyenne, Howell, Henry Fourth, Idaho, Jalousie de Fontenay, Louis Vilmorin, Levard, Marie Louise d'Uccles, Napoleon, Onondaga, Osband's Summer, Paradise d'Automne, Passe Colmar, Pitmaston's Duchesse d'Angoulême, St. Crispin, St. Michael, Star of Bethlehem, Souvenir du Congrès, Sarah, Tyson, Valliant, Vendée, Vicar of Winkfield, Winter Bartlett.

Plums.—The plum orchard contains 173 trees, some of them grafted to several sorts. All of the standard varieties, European, Japanese, and American, are represented here. Fourteen varieties are worth retaining from among the trees planted in the original orchard in 1891. These are: Botankio, Burbank, Czar, English Damson, Grand Duke, Kelsey, Normand's Yellow, Ontario, Petite Prune d'Agen, Rivers' Early Prolific, Satsuma, and Tragedy—besides Marianna for its bearing quality. Other varieties, either small trees or grafted into older stocks, which are doing well and in many cases promise to be very valuable here, are the following: Apple, Bartlett, Caddo Chief, Climax, Cherry, Chabot, Early Red, Evans' Seedling, Golden Beauty, Golden Drop, Honey Drop, Lone Star, Newton, Peach, Pool, Prairie Rose, Perdrignon, Rouge, Shiro, Sugar Prune, Sultan, Wayland, Wickson, Yosemite, and Yellow Onderdonk. The best of all these, and one of the most satisfactory in the entire orchard, is Wickson. Scions of this and of some other varieties sent out by Mr. Burbank, as well as of the best Americans, have been distributed from this substation in recent years.

We now come to the list of plums that, as experience has shown, should be discarded here by nurserymen and tree-planters. The following varieties are unproductive, although the trees grow well and are fit for working over to better kinds. Some of them are known to do well in other parts of southern California, but as a rule these old standard European varieties are not as successful in the southern counties as are the newer Japanese and cross-bred types: Autumn, Barry, Bassford, Bavay's Green Gage, Bradshaw, Bulgarian, Brignole, Black Morocco, Belgian Purple, Columbia, Coe's Golden Drop, Coe's Late Red, Copper, Clyman, Duane's Purple, Datte d'Hongrie, Drap d'Or d'Esperen, Diaprée Rouge, Fellenberg, Green Gage, Glaister, German Prune, Goliath, General Hand, Imperial Gage, Ive's Autumn, Ickworth Imperatrice, Jaune Hâtive, Judson, Jefferson, Lucomb's Nonesuch, Lombard, Long-Fruited, Monroe's Gage, McLaughlin, Mont Barbat d'Ente, Prince Englebert, Peter's Yellow Gage, Puymirol d'Ente, Perdrignon Blanc, Précoce de Berthold, Pond's Seedling, Prince of Wales, Quackenbos, Royal Hâtive, Simon, Smith's Orleans, St. Catherine, St. Martin, St. Lawrence, Vineuse, Washington, Wangenheim, Wine-Sour, Yellow Egg.

Some, and indeed many, of the above varieties have never borne a plum since they were planted in 1891 and 1892. Their uselessness for this district is evident, yet many of these kinds are still being planted by newcomers.

Nectarines.—While some of the nectarines planted have borne as well as the average peaches, the fruit is not in demand and there is no interest shown in its culture. Downton and Stanwick have always had good crops; Elruge does well in some seasons. Lord Napier, Pitmaston Orange, and Rivers' Orange have never borne at all. Victoria bears very poorly, though receiving more water than the rest of the row.

Other Deciduous Fruits.—Peaches are elsewhere reported upon more at length. Seventeen varieties of apricots are grown, one and two trees of each kind having been planted, and some new California varieties have recently been added to the collection. The apricots have not borne fruit since 1899, excepting Royal, Briggs' White, Newcastle, Flickinger, and Hemskirke. The orchard as a whole is unprofitable; apricot culture is still on trial in this district.

There are ten varieties of cherries, representing all types (two trees of each), and fifteen varieties of almonds (49 trees). There are also 81 fig trees (usually listed among semi-tropic fruits), one and two trees of a kind, which collection includes about everything which has been fruited in any part of California, and embraces most of the varieties of Capri grown by Mr. George Roeding. There is also a large collection of Japanese persimmons.

CONCLUSIONS RESPECTING DECIDUOUS FRUITS.

The climatic limitations upon certain lines of deciduous fruit culture here are evidently decisive as regards commercial possibilities. But these limitations only apply to a similar soil, climate, or elevation in southern California, since the success of many of these varieties is well known in districts not many miles from the substation.

Almonds are of medium quality, but the trees have borne good crops only twice in seven years. The trees are extremely healthy.

Cherries have done even worse than almonds, and may be set down as an entire failure here. In fact, the cherry does not succeed anywhere over a large district hereabouts, and the Morello types are little better than the large standard sorts.

Fig trees, while growing very well, and in demand for cuttings to send to various parts of the State, do not bear first-class fruit, whether pruned or unpruned, irrigated or unirrigated, by reason of the "fig-sour," for which no remedy has been found. A few sorts usually escape, such as Angelique, Bourjassotte Grise, and the common Mission Black.

Peaches.—Peaches form so important an item of the deciduous fruit crop that the history of this substation orchard is worth telling with more detail. The earlier reports of the substation show the great value of this crop; but in recent years, some of the Persian types having begun to fail, the orchard has been extended by adding a large number of Southern and other new varieties, which are now beginning to bear. Many of the old trees have suffered from root-knot. The following table shows the crop yielded in four successive seasons by the varieties named. All the trees were well cared for and irrigated when that was needful. Where two trees of a variety bore, the yield given is the average:

PRODUCT OF PEACH TREES, 1898-1901.

	1898.	1899.	1900.	1901.
Alexander	5½ lbs.	32 lbs.	0 lbs.	2½ lbs.
Amsden's June	20 "	30 "	15 "	15 "
Briggs' Red May	14 "	2 "	0 "	3½ "
California Cling	32½ "	50 "	5 "	30 "
Chinese Cling	22 "	20 "	10 "	20 "
Comet	117 "	33 "	40 "	60 "
Coolidge's Favorite	57 "	11 "	10 "	15 "
Crawford, Early	18 "	7½ "	10 "	30 "
Crawford, Late	60 "	15 "	10 "	15 "
Foster	97 "	18 "	22½ "	32½ "
Grosse Mignonne	32 "	10 "	10 "	37 "
Henrietta	35 "	20 "	30 "	30 "
Indian Blood	59 "	20 "	35 "	17½ "
Large Early York	60 "	20 "	10 "	73 "
Lewkins' Honey	(not bearing age)	35 "	40 "	30 "
Lovell	27 lbs.	25 "	30 "	30 "
McDevitt's Cling	16 "	0 "	0 "	5 "
McKevitt's Cling	54½ "	0 "	0 "	10 "
Morris White	25 "	0 "	0 "	15 "
Mountain Rose	37½ "	14 "	5 "	25 "
Muir	43 "	10 "	5 "	22½ "
Newhall	10 "	0 "	0 "	0 "
Oldmixon Cling	89 "	16 "	20 "	40 "
Picquett's Late	31 "	0 "	0 "	5 "
Runyon's Orange Cling	13½ "	35 "	5 "	20 "
Salway	41 "	30 "	40 "	60 "
Sellers' Cling	20 "	30 "	2 "	30 "
Smock's Late Free	55 "	15 "	47½ "	25 "
Stump-the-World	45 "	9 "	10 "	17½ "
Susquehanna	20 "	2½ "	1 "	2½ "
Ward's Late Free	11½ "	0 "	0 "	0 "
Waterloo	10 "	5 "	0 "	15 "
Wilkins' Cling	16 "	0 "	0 "	20 "
Yellow St. John	30 "	21 "	60 "	71 "
Yellow Tuscany	63½ "	8½ "	20 "	30 "

A glance at this table will show any orchardist accustomed to peach-growing on a commercial scale that very few of these varieties are yielding sufficient to pay for planting. When it comes to the question of small family orchards, quite a number of them are worth attention. The reduction in size of crop in almost every case shows the general unsuitability of the standard Persian varieties to this district. The only extremely early peach worth planting is evidently Amsden's June. Briggs' Red May, Alexander, and Waterloo are mere cumberers of the ground. Few varieties yielded more in 1901 than in 1898, and chief among these were Large Early York, Grosse Mignonne, Yellow St. John, and Salway. The falling off in the crops of such standard varieties as Crawford Late, Smock's Late, Foster, McKevitt's Cling, Muir, and Yellow Tuscany was remarkable. For the four seasons as a whole, Comet, Foster, and Oldmixon Cling were the best bearing kinds.

Salable Varieties.—The foreman reports that the following twenty varieties have given the most satisfaction: Comet, Crawford Early, Crawford Late, California Cling, Coolidge's Favorite, Ford's Improved, Foster, Lovell, Lewkins' Honey, Heath Cling, Henrietta, Muir, Mountain Rose, Runyon's Cling, Salway, Smock's Late, Seller's Cling, Stump-the-World, Yellow St. John, and Yellow Tuscany. The quality and appearance of all these varieties are unusually high. The only trouble is in the smallness of the crop in many cases. It is this difficulty that is being met by testing many new varieties of types other than the Persian.

New Varieties on Trial.—Among the new varieties now planted are the following: Angel, Admiral Dewey, Belle of Georgia, Beauty's Blush, Caton, Climax, Dwarf Japan Blood, Dorothy, Estella, Florida Crawford, Everbearing Francis, Peen-to, Red Ceylon, Suber, Waldo, Waddell, Victor, and Victoria.

Peen-to has proved to be a vigorous grower and very prolific, but the fruit is of poor quality and small, though severely thinned. It begins to show up on the fruit stands of Los Angeles, however, coming from the foothills, and its earliness makes it desirable. It is very subject to leaf curl. This variety has been known to ripen from ten to fifteen days earlier than the Alexander.

Angel, an improved Peen-to, a new Southern peach, is one of the best early varieties at the substation, and "bears heavily every year," so that it is to be recommended for general planting in southern California.

Honey (freestone), of the South China type, a very sweet medium or small peach, bearing some crop every year, even when the standard varieties fail, is being widely disseminated by the substation. So also is the old Chinese Cling, a North China variety, poor for canning, but a choice, well-flavored cling for other uses, and a regular bearer, even in unfavorable seasons.

The true Elberta proves to be one of the best peaches grown here. It makes a large, vigorous tree, bears well, and the fruit is of fair quality for a large, yellow variety.

Reviewing the subject of peaches for this district, we reach the conclusion that the Southern types grown extensively in Texas, Georgia, and Florida, are the most promising for future experiment, but that crosses upon the best Persian varieties, so as to obtain their size, firmness, and quality, will be required by the orchardists of southern California.

OLIVES.

From the commercial standpoint, olive-culture in this district in recent years has not been as prosperous as it was formerly. The olive crop at the fine orchard of the substation has been small for several years past. There are about 150 trees, including all the varieties grown in California. Less than half a dozen varieties, however, have been bearing well in recent years, although the trees receive the best of culture, have been fumigated to destroy the scale, and are well irrigated. Columbella, Mission, Rubra, Manzanillo, and Pendulina have been among the best-bearing varieties here. The value of this representative collection, which is now one of the best in California, is not lessened for study and distribution to other districts by the fact of the non-bearing of so many sorts here.

Frost Effects on Olives, 1901-2.—The following notes upon the comparative hardiness of olives were taken by Mr. Mills, the foreman: The lowest temperature ranged down to 23° and 28° (in December and January). The crop of Ascolino was badly frozen. It was light, and the olives were ripe when the frost came, December 13, 1901. The crop of Santa Catarina was only slightly hurt. The fruit was ripe, but only that on the southeast side was damaged. Oblonga was very badly frozen. There were few olives on the tree. Regalis, Polymorpha, Picholine (true), and Macrocarpa all had ripe fruit, which was destroyed by the frost. Columbella had the ripe olives destroyed and the green ones badly injured. Manzanillo had both ripe and green fruit ruined. Præcox and Rubra bore a small crop, which was but slightly hurt. Nevadillo Blanco, Pendulina, Huff's Spanish, and Picholine St. Chamas, all with very small crops, were badly damaged. Cayon stood the cold well. The crops of Attica and Mission, the fruit on which was still green, were very little hurt by the frost. The Dalmatian olives were ripe and picked before the freeze. Redding Picholine bore very little, but stood very well. The above twenty varieties were all that had any fruit. No olives had been frozen at the substation in previous seasons. Most of the crop has been picked before the severe frosts, but the "left-overs" have not been frozen heretofore. The trees themselves have never been injured by frost.

CITRUS FRUITS.

Oranges and lemons have done well in recent years, and the grove is an excellent representative collection. The orange crop of the spring of 1899 was 5,847 pounds, from 58 trees; that of 1900 was 6,727 pounds, from 59 trees; that of 1901 was 8,671 pounds, from 54 trees; that of the spring of 1902, the season just passed, was 3,444 pounds, from 39 trees, the late Valencias not being ripe, and losses from splits and windfalls being greater than usual. The last estimate was made May 1, 1902.

Comparative Yields.—The following table shows the yields for four years of selected trees in the grove. Two trees of Washington Navel were taken. The large crops of some other varieties will be noted, which for home use here are excellent, although less valuable for market than Washington Navel. The average crops of all the trees in each case (last column) shows that Magnum Bonum and Pineapple have yielded much the best crops. The "good" tree of Washington Navel was one of six whose average was 154 pounds per tree per year. These six would therefore rank, in point of productiveness, as No. 5 on the list shown in the table, or below Ruby. The best tree listed ranks as No. 3 in the table, being surpassed by both Magnum Bonum and Pineapple.

COMPARATIVE YIELDS OF VARIETIES.

Name.	Crop 1899 lbs.	Crop 1900 lbs.	Crop 1901 lbs.	Crop 1902 lbs.	Av'ge per year.	Remarks.
Wash. Navel ......poor tree	23	110	88	63	71	Crop average of 12 trees was 96 lbs. per year per tree.
Wash. Navel ......good "	79	340	344	70	208	
Pineapple......... " "	246	286	375	127	257+	Crop average of 4 trees was 187 lbs. per year per tree.

COMPARATIVE YIELDS OF VARIETIES—*Continued.*

Name.		Crop 1899 lbs.	Crop 1900 lbs.	Crop 1901 lbs.	Crop 1902 lbs.	Av'ge per year.	Remarks.
Ruby	good tree	177	186	314	150	206+	Crop average of 4 trees was 156 lbs. per year per tree.
King	" "	60	6	192	...	86	Crop average of 2 trees, as above, 64 lbs.
Tangerine	" "	60	36	27	28	37+	Crop average of 4 trees, 3 years, was 43 lbs. per tree.
Jaffa	" "	100	16	150	...	88+	Crop average of 4 trees, 4 years, was 64 lbs.
Homosassa	" "	199	192	211	147	187+	Crop average of 4 trees, 4 years, was 165 lbs.
Valencia Late	" "	53	119	188	54	103+	Crop average of 2 trees, 3 years, was 130 lbs.
Magnum Bonum	" "	381	255	258	200	271	Crop average of 4 trees, 4 years, was 191 lbs.
Parson Brown	" "	218	160	277	68	180+	Crop average of 4 trees, 4 years, was 153 lbs.
Malta Blood	" "	35	165	320	84	151+	Crop average of 2 trees, 4 years, was 118 lbs.
Medit'an Sweet	" "	132	50	271	136	147	One tree.

Frost Effects on the Oranges and Lemons.—The citrus fruits were noticeably hurt by the frosts of December 13, 1901 (23°), and January 29, 1902 (28°). On the 30th of January Mr. Mills noted the condition of the trees and made an excellent report, from which I quote as follows: The orange trees that are large and well-grown were practically uninjured, only the late fall growth being injured where it was exposed to the rays of the rising sun, causing the wood to die back to the last summer's growth. Young orange trees of last summer's planting were killed back nearly to the ground, even when wrapped with two thicknesses of Japanese matting. The trees of Kumquat, Kino-Kuno, and Oonshiu were not injured, but the fruit of the latter was ruined, all the cells being dried out on one side, even when not exposed to the sun. The effect of frost on the fruit of the orange is shown (1) by the drying out of the cells, (2) by the disintegration of the cells and the separation of the divisions of the pericarp in the center of the orange, and (3) by the shriveling of the whole fruit, rind and stem.

The first condition has heretofore been the most noticeable, but the second now seems to be more prevalent than usual. Fruit affected in the second way is full of juice, but it is thin, insipid juice, which is confined to the inside of the divisions of the pericarp, but is both inside and outside of the cells. Such fruit is soft and mushy inside, has a bad taste, and will not keep under any condition. The outside appearance of such fruit would indicate that it is first class except to an experienced eye. Majorca, Malta Blood, and Mediterranean Sweet seem to be most severely affected in this way, although the trouble extends to the Navel oranges in some of the Pomona groves.

The shriveled fruit (type 3) seems to be affected by the stem having been injured by the frost. Such fruit is heavy and full of juice, but the shrunken skin renders it unsalable.

The thick-skinned oranges of all varieties have the fewest empty cells. A striking example of the immunity from frost of thick-skinned and dormant oranges was afforded by a common seedling tree at the lower end of the grove, which had been gophered and had not made any growth last season. The foliage was so small and thin that the oranges could be seen all over the tree from any direction. The fruit was of ordinary size with rather a thick skin, but six weeks after the frost it was heavy, full of juice, and of fine flavor. Specimens picked from the most exposed portion of the tree showed no ill effect from the frost. The trees have a healthy, green color, but the leaves are less than half the normal size. The foliage did not show any ill effect of the frost other than a dull appearance for a short time afterward.

St. Michael, Oonshiu, and King were the most seriously injured, most of the cells being dry. Tangerine (Dancy) had fifty per cent of the exposed fruit injured by the frost, but that in protected parts of the tree was uninjured. At the station the Washington Navel is injured most by the shriveling of the whole fruit.

Protection Against Winds.—The location of the substation, in the middle of the valley, renders some protection against wind storms useful. A number of eucalyptus trees grown at the Santa Monica station have, therefore, been planted on the eastern side, across the road, on vacant land belonging to the Chino Company, who gave permission, and will leave the trees as long as desired.

It is the general experience of growers that citrus trees need all available protection in localities subject to frosts or violent winds. Other things being equal, trees which have been injured by wind storms become more susceptible to frosts. Dense windbreaks improperly located may, however, serve to collect cold air, and so increase the frost injury to an orange grove. When an orchard entirely inclosed by a dense windbreak is situated on a slope, the frost damage as a rule increases toward the lower side. Sometimes the central portion is most affected, owing, it is probable, to insufficient irrigation. The lower end of a sloping orchard is likely to have a surplus of water, and the upper end gets some surplus from the head ditch, but the middle portion often suffers, and trees there may be severely injured by frost. In many cases it has proved useful to divide an orange grove into plots of two or three acres by windbreaks. The loss of land is considerable. Windbreaks, especially when intended to shelter larger areas than two acres, should not be too dense; trees planted in small clumps, or if in rows, with space between to let the wind pass, while somewhat breaking its force, are better than "tree walls" or hedges.

In many places, especially in a foothill country, it is practicable to study the wind currents and direct or modify them by planting masses of tall trees, even at a considerable distance from the orchard or house to be sheltered, instead of in a close, high wall around a few acres. In the middle of the Chino Valley, where all that is needed is some shelter against occasional wind and sand storms, a small block of eucalypts will be of considerable service in protecting the orange grove.

THE VINEYARD.

A large number of cuttings of valuable grapes continue to be distributed from the vineyard of the substation, which is about four acres in extent and includes nearly two hundred and fifty varieties. This season, shipments were made to many points, but the vineyard at Tulare still supplies more cuttings than any other substation. The experimental vineyards of the various substations now form the largest and most available collection of European grapes known to exist in the United States, and they have been drawn upon in recent years by various other stations and by foreign governments.

Grafting on Resistant Stocks.—In March, 1901, Mr. Bioletti, then viticulturist of the Department, went to the substation and carried on some grafting experiments on resistant roots of various sorts. The percentage of successful unions was low, owing to the injury of many young vines by the hot sun.

The principal work done was with Muscats; other small lots grafted were only to test the affinity which they might have with different varieties of resistant vines. In France the Bouschet grapes, it is said, have little affinity for resistant stocks; but some of the best unions made at the substation were with Alicante Bouschet.

In all cases the grafts were examined and any roots rubbed off from the upper scions in May and in July, when the raffia ties were cut. The ground was irrigated when needful. An excellent growth was made in most cases. Mr. Mills reports that "long grafts," that is, long cuts of an inch and a half at the point of union of the two scions, develop less knot than short unions do, and are in every way preferable. The following table shows results of this grafting:

GRAFTS ON RESISTANT STOCKS.

Name and Stock.	Number Planted.	Total Number Which Grew.	Number Which Made Good Unions.	Number Which Made Poor Unions.	Average Growth in 1901.
Muscat on—					
Rupestris St. George	680	95	60	35	9 to 14 in.
Rupestris Martin	374	89	69	20	9 " 12 "
Riparia × Rupestris 101	749	151	121	30	9 " 12 "
Riparia × Rupestris 3309	798	254	179	75	9 " 12 "
Riparia Gloire de Montpellier	50	7	7	0	9 " 12 "
Riparia Grande Glabre	58	8	8	0	9 " 19 "
Palomino on—					
Rupestris St. George	34	5	5	0	24 " 40 "
Riparia × Rupestris 101	38	5	2	3	24 " 48 "
Riparia × Rupestris 3309	38	8	7	1	24 " 40 "
Riparia Grande Glabre	34	3	2	1	24 " 40 "
Rupestris Martin	40	6	4	2	12 " 24 "
Feher Szagos on—					
Rupestris St. George	11	2	2	0	12 " 18 "
Rupestris Martin	11	0	0	0	-- --
Riparia × Rupestris 101	11	2	2	0	12 " 18 "
Riparia × Rupestris 3309	11	0	0	0	-- --
Riparia Grande Glabre	12	1	1	0	15 "
Sultanina on—					
Riparia × Rupestris 101	29	2	2	0	15 " 25 "
Riparia × Rupestris 3309	28	8	8	0	15 " 25 "
Rupestris St. George	28	2	2	0	24 "
Rupestris Martin	30	5	5	0	24 " 35 "
Riparia Grande Glabre	30	3	3	0	24 " 35 "
Sultana on—					
Riparia × Rupestris 101	12	3	3	0	16 "
Riparia × Rupestris 3309	12	3	3	0	16 " 20 "
Rupestris St. George	12	1	1	0	24 "
Rupestris Martin	(?)	3	3	0	15 " 24 "
Alicante Bouschet on—					
Riparia × Rupestris 101	17	5	3	2	10 " 18 "
Riparia × Rupestris 3309	18	9	9	0	15 " 24 "
Rupestris St. George	20	4	4	0	15 " 24 "
Rupestris Martin	20	1	1	0	18 "
Riparia Grande Glabre	20	1	0	1	12 "

New Grapes from the Department of Agriculture.—The department sent, in the spring of 1901, cuttings of ten new varieties of grapes, under Nos. 5908–5918. All these were grafted into ten-year-old vines of Bakator, and small pieces were rooted in the nursery. One variety, No. 5911, made a feeble growth and finally died, both grafts and cuttings, so that this kind is lost. The other nine varieties made first-class growth, furnished from 80 to 279 cuttings of each sort in the fall of 1901, subject to orders from the Department. The longest cane of No. 5419 grew 15 feet in the season. Nos. 5909, 5910, and 5913 grew very late, and more or less of the wood was killed by frost; Nos. 5917 and 5918, like 5914, ripened thoroughly. Nos. 5915 and 5916 were only fairly well ripened.

One graft, that of No. 5913, which made a growth of 15 feet, bore two crops of grapes. One bunch was over a foot long. The fruit was dark blue with a tough skin. The vine was very prolific, and bore and ripened grapes till frost. Another variety that bore two crops was No. 5912, a fine white grape. Mr. Mills measured the growths made by these vines, one of each of the nine varieties grafted, and found that the total length of main canes and laterals was from 100 to 380 feet each, an excellent illustration of the rapidity with which grafts on strong, old vines develop under favorable conditions.

Notes on Table Grapes.—Mr. J. W. Mills, the foreman, furnishes the following brief, practical notes upon various varieties of grapes used here for the table, and some of them as noted for wine:

Alicante Bouschet is a favorite table and cooking grape in this locality, the bunches being of good size, and the vine a heavy bearer. It is also in demand with wineries.

Almeria is very late here, ripening in November and December. It is a shy bearer, and is not recommended for the sandy soil of the Chino valley.

Black Corinth is also late. The bunches are long (8 to 14 inches) and loose. The berries are a little smaller than those of Purple Cornichon, of good flavor when ripe, and keep well. This grape cracks but slightly under the early rains. Pruned long and tied to a stake, Black Corinth produced abundantly in 1901 (some vines 70 pounds), after having been killed back by frost on March 31st when the growth was 2 to 4 inches long, thus showing its hardiness.

Black Morocco is a good, late black grape of largest size; bunches medium size. It yields large second crop, and is recommended for this section.

Black Muscat yields large, poorly filled bunches (badly affected with coulure). It is of good quality, but is not very prolific.

Blue Portuguese is very early, the first ripe being in August, and is prolific, whether pruned long or short, so that we recommend it for trial in the Indio district.

Bowood Muscat is a slight improvement on the Muscat of Alexandria, and in fact, the best of the Muscats here.

Chasselas Rose is a general favorite, and is excellent for home use. Vine, bunches, and berries are small, but early.

Cinsaut holds its reputation in dry, sandy soil. It is very sensitive to frost, even when the buds are not yet open, but highly deserves trial in the Indio district.

Cipro Nero is the best late purple shipping grape here; ripens in November. The vines are prolific, whether pruned long or short. The bunches and berries are large and fine. Most of the crop was ruined in 1901 by early rains.

Emperor: The vine grows rankly, and produces well when young. Grapes are few, but all are large and well-shaped, though poorly colored and of inferior flavor. It can not be recommended for this section.

Flame Tokay is neither prolific nor very well colored here. The soil is too light for this grape.

Golden Queen is extremely prolific; the bunches are large and perfect. It is a late sort (November), and a good keeper. The bunches of this grape have the appearance of first-class Muscats, except that the shoulders are less prominent. It does not crack when rained on, but decays in small brown spots when prolonged wet weather occurs.

Gros Colman bears well and the berry is of good quality, but is smaller than elsewhere. The variety does not stand extremely warm weather, and the bunches are nearly all imperfect.

Luglienga is a white and early variety (July), and one of the shyest of bearers, but of good quality. It is not adapted to the sandy soil of Chino Valley.

Malaga is a very rank grower, but not prolific. Vineyards of this grape in this neighborhood have been taken out.

Muscat of Alexandria is a poor producer, and bunches imperfect.

Muscatello Fino is a poor bearer, but of best quality. The vines recovered well from frost in 1901.

Napoleon: This grape ripens in September and October. It is prolific; a sure cropper. Berries and bunches are of good size, and on the whole it is one of our best late white grapes.

Olivette de Cattane is about the best all-season white grape here. It ripens early in August, and holds its good quality until December. The vine is a strong grower, the bunches are full and large; it is moderately productive.

Pizzutello di Roma is a white, crescent-shaped, tender and crisp grape. Its seeds here are strong in tannin and not agreeable in taste; it is a medium bearer.

Purple Damascus is an early grape with large bunches and berries, but badly affected with coulure. The quality is not first rate. This variety is excellent for arbors but not for vineyards, but it would suit the Indio district.

Quagliano: This grape is of medium quality, but a poor keeper, and therefore not recommended.

Sultana is the best of the seedless grapes for this region.

Thompson's Seedless is a shy bearer, and not worth planting here.

Torok Goher Noir seems nearly identical with Gros Colman, but the berry is larger and the bunches are larger and more perfect. It is an excellent large black grape.

Trivata resembles Black Morocco, but is inferior in quality. It is very late, the second crop constituting the bulk of the product. It is spoiled by early rains every year, and is slow to recover from the spring frosts.

Verdal is a fine white grape, which ripens late (October or November). It is tender, and of fine quality. The vine is prolific, and a rank grower.

White Tokay is only moderately prolific, and not recommended.

Zabalkanski has long, imperfect bunches, ripening unevenly, and is always affected with coulure.

The list of Persian grapes includes some excellent sorts, but Alakahee, Ashanee, Rish Baba, and Hutab have imperfect bunches and bear poorly. Pizzutello di Roma resembles these, but is more productive and has better fruit. Askaree is a very early Persian grape with medium-sized bunches and berries. The fruit is white and very crisp and sweet. The vine is not as rank a grower as other Persian varieties. It is worthy of trial in Indio. Black Shahanee is early (August) and very prolific; its bunches are of good size, but the berries are less than medium. This also is worthy of trial in Indio. Chavooshee ripens in September; it has large, long, loose bunches, and the berries are the size and shape of Cornichon, and white, crisp, and of good flavor. Khahallee also ripens in September. The bunches are medium; the berries are of good size, bluish-black, pointed, and very crisp and sweet. It is a favorite with all, and can be highly recommended. Payhanee Razukee is a red, early grape, a poor producer, and badly affected by coulure. It is very attractive when grown and might do better in Indio. Persians Nos. 20, 22, 23, 24, 25, and 26 are always barren, although the vines make a prodigious growth. No. 21 produces a few fine bunches of large-sized grapes, earlier than Thompson's Seedless by two or three weeks.

American grapes are more or less in demand in southern California, and cuttings are often asked for.

Agawam ripens in September. It is a reddish-brown, large grape of extra fine flavor and is moderately prolific.

Aminia ripened on August 8th. It is a large black grape with heavy bloom, and of good flavor.

August Giant ripened on August 15th. It is a large purple grape and unproductive.

Brighton ripened on August 5th. The fruit was above medium size, sweet, of good flavor, and very tough.

Brilliant ripened on August 10th. The bunches were small and close, of dull red color, good flavor, sweet, tough flesh, and tender skin. It is very prolific and bears a heavy second crop.

Campbell's Early ripened on August 5th. The fruit is purple in color, of large size, mild flavor, and sweet with moderately tough flesh. This variety yields a very large crop.

Dr. Hexamer ripened on August 10th. The fruit is reddish, with heavy purple bloom; quality is poor.

Governor Ross ripened on August 5th. It is a white grape, of medium size, and delicate flavor.

Green Mountain ripened on July 20th. The fruit is white, small, sweet, and moderately tender.

Herbert ripened on August 12th. It is a large, reddish purple grape and a good bearer.

Lindley ripened on August 10th. It is a bright red grape, above medium size, with tough skin, tender flesh, and good flavor.

Moore's Diamond ripened on August 5th. It is a white grape, of medium size, fine flavor, sweet and tender.

Rockwood ripened on August 8th. It is a small, black grape with heavy blue bloom; flesh tough, sweet, and of good flavor.

In the above list of American grapes Campbell's Early and Agawam are the two best varieties for this locality. Moore's Diamond is better than the average in all respects, and Governor Ross could be recommended excepting for its shyness in bearing.

SMALL CULTURES.

At this substation, a large number of the varieties of seeds sent out by the Department of Agriculture have been tested at various times, on both the home tract and the moist land. Some had been previously grown here, and others were new to the district.

Alfalfa.—This crop is one of great importance in the district, and more is sown every year. It usually does well on the ten-acre tract without irrigation, though dodder, and in a few spots strong alkali, have injured it. On the home tract irrigation is needful. The Turkestan alfalfas sent out by the Department have proved a valuable acquisition. Nos. 1150, 1151, and others of the Hansen collection were sent here in 1899, and have been tested ever since. Planted in the spring of 1900, Nos. 1150 and 1151 were 6 inches high by July. At first no difference in growth between these and the common alfalfa could be observed. Gophers destroyed a good deal of all the alfalfas this year, as in spite of all efforts to poison them, they "came in" from the surrounding fields, which were barren. Turkestan and other alfalfas were again sown in 1901. At the end of March, 1902, the Turkestan alfalfa was twice as high as the common kinds under the same conditions, both plants several years old and the younger plants. Sown on the dry land of the home tract, both Turkestan and common alfalfa died from drought. On any good alfalfa land here, the Turkestan varieties soon take the lead. At Paso Robles substation, the Turkestan alfalfa was not as large as the common alfalfa, but stood drought better, although here a local variety was even better in regard to drought-resistance.

Asparagus Chicory (*Cichorium intybus*), No. 4360.—This was planted on the moist land of the ten-acre tract. It grew 3½ feet high. The rosettes of much-thickened leaves were not locally in favor when cooked, a great variety of vegetables being easily grown in the district.

Bassia dallachyana.—This is an erect undershrub whose fruiting calyx is covered with a dense cottony substance. It has been suggested that this might be valuable for cotton or felt. Seeds were sown in the greenhouse, spring of 1901, and transplanted to the field, home tract, where they grew vigorously and are 3 feet high or more. Sheep eat this plant readily, but Dr. Koch says when in fruit it is injurious to livestock.

Broad Beans (*Vicia faba*).—These hardy beans, justly becoming popular in the coast valleys of California, have now been tested for several seasons at this substation both on the home tract and the ten-acre plot. A complete collection was obtained several years ago from Vilmorin and another from Sutton. Nearly all the Department of Agriculture importations have also been tested (Nos. 3628, 3751–58, 1453, 1454, and others), with the same results. Where early autumn sowing and winter irrigation can be practiced, the broad beans are worthy of further trial, but not for ordinary field conditions in this district.

Broccoli.—Nos. 4355–9, five varieties from Naples, Italy—the Purple Navidad, Santa Teresa, White San Isador, San Martinari, and Gennarese—were sown March, 1900, on the ten-acre tract. They came up well, but many were killed by alkali while the cotyledons were still expanding. The few that remained made a poor growth, it being a very dry year. Nos. 4482 and 4483, also from Naples, and planted about the same time on the ten-acre tract, were also much injured by alkali. The tallest plants were 2 feet high. Autumn-sown broccoli and cauliflower suit the district admirably if planted on any fairly good soil.

Burdock (*Lappa major*).—One variety of this plant, used in Japan as a vegetable, was grown at the substation, on the home tract, several years ago, and grew very well. Nos. 4981, 4982, and 4983 of the Inventory were grown in 1900 and 1901 on the ten-acre tract, where the alkali destroyed the plants.

Carrots.—Eight varieties of field and other carrots were grown on the moist land in 1901. They stood the alkali fairly well, but the yield was surprisingly low for a soil which yields so well in beets. The yield of the best per acre was as follows: Long Horn, 4.25 tons; Large White Vosges, 3.75 tons; Improved White Short, 3.25 tons; Large White Belgian, 1.5 tons; Red Meaux, 1.25 tons; Long Red Aldringham, .75 of a ton. The ordinary yield of Long White Belgian on such soil as this, but free from alkali, should be not less than 12 tons, and in any case the yield of the White Short would be much less. The above results are probably traceable to the evil effects of alkali, which were greater on the deep-rooting sorts.

Chards (*Beta vulgaris*).—This, the "Swiss Silver-Ribbed," Nos. 4361 and 4362 (curled), was planted on the ten-acre tract. Both varieties suffered from drought and blight. The Chilean scarlet and Chilean yellow (both classed with the chards), more often used for ornamental purposes, Nos. 4363 and 4364, have also been grown here in previous seasons and have thriven very well. As a rule, there is little blight on any variety of beet. March 28th was the time of planting these chards in 1900.

Cotton (Egyptian varieties).—In previous reports will be found notes upon large collections of cottons, chiefly upland, grown here. The Section of Seed and Plant Introduction, now a part of the Bureau of Plant Industry, sent out in January, 1901, four varieties of Egyptian cotton (Nos. 3991, 3993, 4330, and 4329) for trial here. No. 3991 was the noted Jannovitch, which originated as a sport from the Abbasi, and was brought to notice in 1897. It is said to be the finest long-staple cotton ever produced in Egypt. No. 3993 is also a fine, silky, very long, white staple, and the variety is derived from the Mitafifi, which, however is a brown-fibered variety. No. 4330 is the Abbasi, a long-staple white cotton, which brings the highest price of any Egyptian variety.

The seed received from Washington was old, and thick planting was advised. The previous rainfall of October and November, 1900, was 8.72 inches; of January and February, 1901, 7.36 inches; of March, April, and May, 1901, only one inch. May 20th the cotton was planted in hills 4 feet apart each way. The stand was very poor, only about half of the hills showing a plant. A portion of the ground, where an alfalfa field had been plowed up, gave an excellent stand. No irrigation was given, but the cotton plants grew well until the frosts killed them to the ground. They were cultivated three times.

This Egyptian cotton bloomed August 1st, but all the early flowers fell and only those which came out about September 1st set bolls. Only a few of these ripened, but sufficient seed was obtained for planting in 1902. A few hills of Doughty's Extra Long, a Southern variety, were planted for comparison. Under the same conditions, the Egyptian far outgrew the American cotton. On the driest land it was 18 inches high; on the best land, fertilized by plowing-under alfalfa, it was 4½ feet high. All the Egyptian varieties rooted much deeper here than did the American sorts, and it seems in this respect much healthier and better adapted to California conditions. But the season is very short for them, and early planting is needful, although acclimatization may do much in this respect. They require close planting to induce a more upright growth and to better protect them from the winds, as they seem to split more easily than do the common varieties. On the best soil, the bolls were as large as the average cotton grown here. Unlike the Peruvian cotton, which has never succeeded at any of the substations, the Egyptian varieties justify more extended trials and comparisons with more of the approved Southern varieties.

Cucumbers.—No. 4989, received under the title of "cucumber from Japan," produced a long, yellow, sour, muskmelon-like fruit. No. 4990 was a poor cucumber, also from Japan. The soil at the home tract, in years of ordinary rainfall, is well adapted to the growth of cucumbers and melons of every sort.

Enchylæna tomentosa.—Seed of this "drought-enduring undershrub" from Australia (No. 4287 of the Department) was sown in the greenhouse, and plants put in the open ground of the home tract, but all died, although some were watered every few days.

Field Peas.—No. 1486, the "gray winter field pea" of France, was planted on the home tract in 1900; it suffered from drought and made poor growth. The roots showed no tubercles. No. 1173, the large Victorian field pea, sowed November, 1899, made a brilliant record as regards growth, reaching by April, on the home tract, the height of 3½ feet. It showed value as a green-manuring plant for early sowing. This pea does not make much seed here, hardly yielding as many peas as were planted, but in moister soil would doubtless yield well.

Gourds.—No. 4999, the well-known "wax gourd" (*Benincasa cerifera*), planted April 30, 1900, failed to grow by reason of drought. Other tests of this vine show that it needs warmer nights, and thrives in few places in the district. No. 5000, a Japanese gourd, ripened a few small fruits, but did poorly. A large collection of some twenty varieties and species of gourds and ornamental cucurbitaceæ from various sources was grown here in 1891–93 and seeds locally distributed. The district is very well adapted to these vines, which require no irrigation except in years of short rainfall.

Grasses.—Seed of *Bromus inermis*, No. 3004 of the Inventory, was planted in 1900 on the home tract with Schrader's brome-grass (*Bromus unioloides*). The former scarcely lived and was only 3 inches high by winter; the latter grew a foot high, produced seed and made a good stand. Planted on the ten-acre tract of moist land, *B. inermis* made no showing at all as compared with *B. unioloides*.

Millets.—No. 2795, sown on the ten-acre tract in May, 1901, suffered from alkali and only grew 8 inches high. This was one of the broomcorn millets of the Carleton collection from Russia. No. 1387, a Turkestan millet of the Hansen collection, grew but 8 inches high and headed out. It was on the ten-acre tract and suffered from alkali. Millets of every type have been successfully grown on the home tract in previous years.

Muskmelons.—Nos. 3161–64, 3173, and 5774 of the Department were sown in May, 1899, on moist land along the line of the head ditch, but as the water-flow ceased, all the vines died from drought, the rainfall of that season being very small. Nos. 6363 and 6364 were planted in May, 1901, on the home tract, but most of the vines and fruits were destroyed by rabbits and crows. The remaining fruits "split open, because of heavy fogs." A large collection of muskmelon seeds from Turkestan was received. Ten varieties, under the numbers 114, 115, 116, 117, 118, 119, 120, 121, 122, and 123, were distributed in the spring of 1899. None of the twenty or more kinds of these Asiatic melons, as grown at this substation, on sandy soil, unirrigated, proved of high quality compared with the best American and European varieties. All were more or less subject to fungous diseases of the leaves. Some did not bear well. Those distributed were the most healthy and the best bearers. In 1899 the Persian melons failed by reason of drought. In 1900 only a few varieties were planted, and, as before, the vines showed fungous diseases. This was true of vines from all the districts of Turkestan, old and new Bokhara, Kiva, and Amudaria. The Russian muskmelons which proved so successful at some other stations were not received here.

Myoporum montanum.—Seeds of this, the "myrtle bush" of South Australia, a large, edible-fruited shrub (No. 4300 of the Inventory), were sown in the greenhouse and transplanted. The bushes, when 3 feet high, were killed to the ground by the frosts of December, 1901, but have grown again from the roots.

Rye.—No. 1342, the Winter Ivanof of northern Russia, was planted in 1899 on the home tract. The season was exceedingly dry and the grain had no irrigation. Wheat No. 1181, from Turkestan, failed to mature, but rye No. 1342 grew 5 feet high. The seed did not germinate well, and hence the stand was poor.

Safflower.—Seeds of this well-known dye and oil plant (*Carthamus tinctorius*), No. 1345 of the Inventory, were sown on both tracts. On the dry land (home tract) it grew 3 feet high and produced some seed; on the moist land the crop was very large, the plants being 4 feet high. It produced seeds at the rate of 5,500 pounds per acre. The drought-resistance of this plant appeared considerably greater at Paso Robles than at this substation. It thrives over a large part of California, and is of very easy culture.

Sesame.—This famous oil plant of the Orient has been tested on a number of occasions at the substation and has done poorly. Seed sown on the home tract in the spring of 1901 (No. 1386) grew only 2 inches high.

Sorghums.—Nos. 4308, 4309, 4310, 4311, and 4312 were grown in 1900 on the ten-acre tract. None of them made a larger amount of fodder than the varieties previously planted here.

Soy Beans.—Nos. 4912, 4913, and 4914, imported from Japan by the Department, were planted in the ten-acre tract. They matured in succession. No. 4912 began to ripen seed August 15th; No. 4913 by September 10th, and No. 4914 by October 1st. The soy beans have done extremely well for several seasons, and all available sorts have been sown. The early and medium early varieties, although not yielding as heavily as the late in some years, are the safest for general planting here.

Sugar Beets.—No. 3941, the White Improved of Vilmorin, imported by the Department for coöperative experiments under the direction of the Division of Chemistry, was grown in 1900, and the beets shipped to Washington.

Sweet Fennel (*Fœniculum dulce*).—In the spring of 1900, Nos. 4367, 4368, 4369, 4370, 4484, and 4485 were sown on the ten-acre tract. These were all fine Italian varieties. Only a few specimens of each variety survived the alkali, but these prospered and grew to a height of 4 feet. These varieties were again sown in the spring of 1901, but alkali prevented growth. In good soil, this plant thrives here. In 1900 it grew well with a rainfall of only 9.58 inches.

Tribulus hystrix.—This is an annual herb from South Australia, considered there a very useful fodder plant (No. 4301 of the Inventory). The seeds sown in the spring of 1901 grew readily, but the plants developed slowly and have not made seed.

Turnips.—No. 4968, a turnip from Japan, was sown on irrigated ground, April 30th. It "ran up to seed almost immediately." Turnips sown here with the early rains in October or November are excellent.

Vegetable Marrows.—Several varieties of this form of *Cucurbita pepo*, so well known in Europe and used as "summer squashes," have been grown for two or three seasons. Nos. 4365 and 4366 from Naples were planted early in May, 1901. In 1900 these two varieties and also the former collection sent out by the Department (Nos. 3132, 3133, 3136, 3137, 3141, 3145, 3148, etc.) had been grown. Seed of four of the most distinct have been distributed. These vegetable marrows were found superior to the ordinary summer squashes of the seedsmen. The Cocozella of Geneva was one of the best. Nos. 4365 and 4366, the latest plantings, produced five to ten fruits per vine, size 3 to 4 inches in diameter and 18 inches long. They were good keepers when ripe; piled under a tree in the field, they kept perfectly for a year. The quality as a winter squash was not equal to Hubbard, nor as a summer squash were these varieties considered superior to Fordhook.

Vicias.—None of the vicias so successful elsewhere have as yet done well at this substation. *Vicia monantha*, the one-flowered lentil of France, a noted forage annual, planted on the sandy soil of the home tract, grew only 6 inches high. *V. fulgens* (No. 1514), *V. sativa* (No. 1507), and *V. narbonensis* (No. 1509) were no better. None of them made seed. On the ten-acre tract, the vetches suffered from alkali. They can be expected to do better in the foothills surrounding Chino Valley.

Watermelons and Stock-melons.—No. 4269, "Mathis, from South Carolina," was planted on the home tract early in May, 1901. It was an excellent melon, but the vines did not grow as well as the old Mountain Sweet. The best stock-melon ever tested at the substation, and one well worth wide distribution, is the Tsama or Khama melon (see Plate 11), a native of the Kalahari desert in South Africa. This seed was sent out several years ago by the Division of Botany at Washington. It did but poorly at first, but now, after three years of further trial, it is evident that it yields about twice as much to the acre as does the Kansas stock-

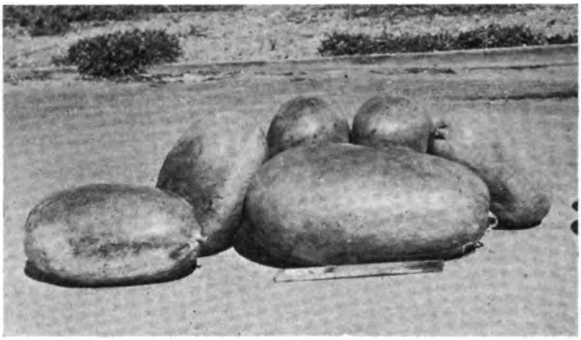


PLATE 10. KANSAS STOCK-MELON.

PLATE 11. TSAMA OR KHAMA MELON.

melon, and stands drought better. The illustrations show comparative yields of two hills grown under similar conditions, on poor, sandy, unirrigated soil. The rainfall was 17 inches; but the melon has done quite as well with only 9 inches, and seems as drought-enduring as the wild gourds and cacti which thrive with an annual rainfall of only 4 or 5 inches. The melons are small, round, covered with small prickles, and are not attractive, but stock eat them readily, especially when somewhat wilted. They keep extremely well. Seed of this stock-melon has been widely distributed by the University for two seasons past, and the seedsmen are beginning to grow and advertise it.

SANTA MONICA FORESTRY SUBSTATION.

(Near the mouth of Santa Monica Cañon, two miles west of Santa Monica.)

This forestry substation was established in the winter of 1887-8 by the State Board of Forestry, and was transferred by the State to the University of California, July 1, 1893. The forestry plantation of 29 acres near Chico came under the control of the University in the same way. The State Board of Forestry was abolished by the same Act which made the transfer.

For the first two years the sum of $2,000 per annum was granted by the State for forestry purposes, and this was raised to $2,500 per annum in 1895-6, but all direct State aid ceased at the close of 1896-7, since which time the University has made small annual appropriations, at no time equal to those formerly made by the State. The progress of the substation has therefore been slow, as lack of means prevents many needed improvements. The policy has been to spend the larger share of the appropriation at Santa Monica, and to keep a foreman there.

While the Santa Monica substation is in some respects the most attractive of all the substations, as it possesses a practically frostless climate, it is better suited for a botanical garden than for pure forestry, for which, indeed, the area is too limited. It affords an excellent location for tests, on a small scale, of acacias, eucalypts, pines, and a few other classes of trees, and now that the water-supply is ample, its unique value, possessed by few places in the United States, lies in the direction of a botanic garden, in which a great variety of plants from all parts of the world could be grown.

Changes and Improvements.—The substation has had four foremen since 1893—Mr. W. J. Strachan, Mr. John H. Barber, Mr. Charles A. Colmore, and Mr. William Shutt. The latter took charge on September 1, 1900. Mr. Roy Jones, son of Senator J. P. Jones of Nevada, continues to serve as Patron.

The most important improvement since the issuance of the report of 1897-8 consists of an unexpected development of the water-supply, made by Mr. Shutt, as foreman, in the winter of 1900-1901. The daily flow from the new springs, cut by drifting farther into the bank, is about 16,000 gallons, and this enables more land to be irrigated on the lower flat. The hydraulic ram is again used to lift water to the house, and the windmill is no longer needed, except when repairs are being made to the other systems.

Some desirable changes in the roads and grades have been lately made, and about three acres of brush-covered land has been cleared. A good deal of this has been planted with acacias and eucalypts. This is excellent soil, although so steep as to be unfit for anything but trees.

CLIMATE.

The climate of Santa Monica and its vicinity is justly famous for its evenness, and a very great variety of native and exotic plant life is found here, as at Ventura and Santa Barbara. Thorough cultivation is absolutely necessary, however, with the light rainfall, and irrigation is practiced wherever possible. The forest trees grown at the substation, however, have received no irrigation excepting as noted in the following pages. Small trees, when first set out from the nursery, often require a little water. As a rule, this "irrigation" consists of a quart or two of water given to each tree from a barrel on a sled. A hole is made beside the tree and the water poured slowly in. When it settles, the hole is filled up with dry earth. One such watering in April has enabled eucalypts and acacias to take root and grow well thereafter; without it, losses would probably amount to half the stock.

Rainfall.—Since the University took charge of the place, the annual rainfall has been as follows:

Year.	Rainfall.	Comment.
1893–4	7.83 in.	An extremely trying year.
1894–5	14.01 "	Fairly good crops.
1895–6	8.40 "	North winds; crop poor.
1896–7	16.13 "	An excellent year.
1897–8	5.24 "	Crops failed; some large trees died.
1898–9	7.11 "	Crops scanty; some trees died.
1899–1900	8.48 "	Crops scanty; some trees died.
1900–1901	11.54 "	Fairly good crops.
1901–1902	11.65 "	Good crops.

The average rainfall for the above nine years has therefore been a trifle over 10 inches. It would seem to persons unacquainted with California conditions as if this low rainfall would make tree-growth impossible, but the statistics elsewhere given show plainly that such is not the case. In fact, one especial value of this substation is its trial, for a long term of years, of a great number of species of trees under an average rainfall of 10 inches.

The monthly rainfall varies greatly from season to season, as shown by the following table of the precipitation during the past four seasons:

Month.	1898–99.	1899–1900.	1900–01.	1901–02.
October	0.34	1.11	0.25	2.41
November	none	1.25	5.66	none
December	.10	1.59	none	none
January	4.56	2.45	none	1.75
February	.01	none	4.35	3.90
March	1.69	.55	.20	3.27
April	.05	.17	.50	none
May	none	.36	.58	none
June	.36	none	none	none

In practice, a rainfall of less than half an inch in any given month is of little value. The desirable thing is to have "enough rain to start plows" in November or December; then to have heavier rains in January or February, followed by spring showers. The favorable distribution of the rainfall doubles its usefulness. This year (1902, May 1st) some barley on the upper mesa stands 3½ feet high and cuts 4 tons of hay to the acre. Young eucalyptus trees, also on the upper mesa, have made from 3 to 6 feet of growth this season. The above table, however, shows that trees and hay received 2.71 inches of rain before January, and after January nearly 9 inches, all well distributed. The crops are better than in 1894–5, with 14 inches badly distributed through the winter.

Temperature.—Only once during the nine years has the frost injured heliotropes, nasturtiums, cannas, and other tender garden plants in this district, but not then on the middle mesa of the substation, where no serious injury has ever been done to even the most tender eucalypts. The lowest flat, by the creek, has proved too cold and shady for *Ficus elastica* and many other plants. On the middle mesa, where the most valuable plantations exist, the immunity from frost is exceptional. Here are growing Hibiscuses, Bauhinias, the Jacaranda mimosæfolia, Tacsonia manicata, Eucalyptus ficifolia, and many other tender plants. The following table, continuing the record in the annual report for 1897–8, gives the temperature at the substation from June 30, 1898, to April 1, 1902:

MONTHLY SUMMARY OF TEMPERATURE.

	Max.	Min.	Mean Max.	Mean Min.	Mean Temp.
1898—July	79°	52°	74°	57°	65°
August	84	54	78	58	68
September	98	50	76	56	66
October	79	42	71	49	60
November	82	42	69	47	58
December	88	41	68	47	57
1899—January	77	38	66	45	55
February	77	33	59	41	50
March	89	37	64	48	56
April	89	42	66	47	54
May	77	43	66	49	57
June	82	48	68	55	61
July	83	49	73	55	64
August	86	51	73	55	64
September	80	51	73	56	64
October	99	42	71	51	61
November	83	42	69	51	60
December	77	41	66	46	56
1900—January	78	42	67	45	56
February	86	42	69	46	57
March	83	40	66	49	57
April	77	39	65	46	55
May	73	44	66	47	56
June	76	50	62•	70	55
July	95	51	65	75	58
August	96	52	68	77	60
September	96	48	63	70	56
October	86	46	68	50	63
November	92	47	73	54	64
December	86	39	64	47	57
1901—January	71	37	60	43	52
February	87	33	64	48	56
March	87	39	68	48	58
April	71	38	62	47	54
May	66	43	64	50	57
June	80	44	66	55	59
July	81	50	71	55	63
August	84	48	73	56	65
September	82	44	69	51	60
October	92	62	65	52	60
November	82	43	66	47	57
December	80	33	66	43	55
1902—January	82	33	62	42	52
February	69	35	59	42	50
March	73	35	63	42	53

In January, 1898, the thermometer fell to 31°, but 33° is the next lowest winter minimum, and the average minimum of nine years was

35°. The maximum has in nine years but once reached 100°, but every year has gone to 90° or above for a few days. The maximum of 1898 was 98°, and the next highest temperatures of that year were 93° and 89°; in 1899 the two highest temperatures were 99° and 89°; in 1900 they were 95° and 92°, and in 1901 they were 92° and 87°.

THE EUCALYPTUS GROVES.

The plantations of eucalyptus trees at this substation have deservedly attracted much attention for some years past. They have been visited by many persons and reported upon in many forms. Mr. Abbot Kinney's work on Eucalypts contains photographs of single trees here, together with notes upon their growth, etc. Professor McClatchie has also taken many notes and photographs here. Former station reports contain much historical and descriptive material on these eucalypts. (See Report of 1892–4, pp. 428–432; Report of 1894–5, pp. 450–455; Report of 1895–7, pp. 412–426; and Report of 1897–8, pp. 340–351.)

A few of the large trees in the main group have died or have been blown down. These losses seem to have been due in every case to poor root systems, pot-bound or too large trees having been originally used. The younger plantations show no such defects. Others of the older trees will soon have to be removed, but specimens of all the species represented in this grove are now established elsewhere.

The following table shows some of the measurements taken in this, the oldest grove of eucalypts in June, 1902:

	Height.	Girth.
E. amygdalina	23 ft.	21 in.
E. calophylla	38 "	47 "
E. citriodora	61 "	35 "
E. corymbosa	36 "	32 "
E. corynocalyx	61 "	47 "
E. diversicolor	68 "	42 "
E. viminalis	53 "	44 "
E. callosa	32 "	15 "
E. sideroxylon	53 "	52 "

Eucalypts on the Upper Mesa.—The original planting of eucalypts, done on the upper mesa nearly one hundred feet above the middle flat, was in the form of a narrow strip, chiefly on the western side, with a few rows across the south and north. This mesa is a long and very narrow tongue of land nearly level on the top, sloping south toward the ocean. On the east it descends almost perpendicularly to the cañon bottom; on the west the descent, less abrupt, is to the cottage mesa, or middle bench of the substation. The light, gravelly soil, and the height and exposure of this plateau, make the growth of trees difficult. Success here argues similar success on plateaus even farther inland.

The eucalypts planted here in 1889, thinned out in 1893 and 1894, and since then uncultivated, have made in many cases noble trees, with trunks that girth from 25 to 40 inches. Their growth has been lessened in recent years by light rainfall, as most of them stand within sixty feet of the edge of the mesa. In point of drought-resistance *E. corynocalyx*, *E. rostrata*, *E. paniculata*, and *E. globulus* are among the best.

The younger grove on the upper mesa was begun in the spring of 1897, when about eight hundred trees were set out, representing thirty-one species. Other trees have been added since. The soil is light and poor,

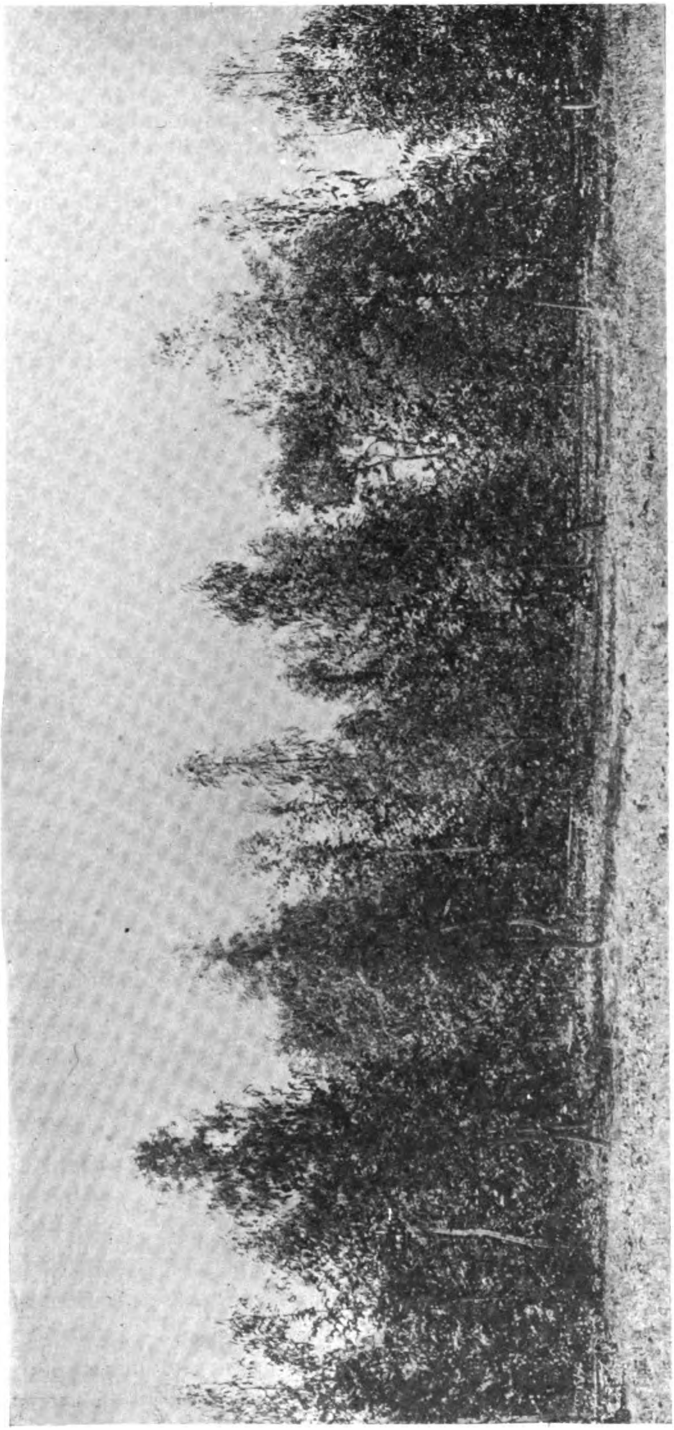


PLATE 12. EUCALYPTUS GROVE, THREE YEARS OLD—SANTA MONICA FORESTRY SUBSTATION.

especially toward the eastern end, and the older trees near by have lessened the growth of the outer row of the new plantation. Nevertheless, the results of the experiment have been instructive, and on the whole favorable.

The well-known blue gum, *E. globulus*, made much the strongest growth in this plantation, and most of the trees had to be cut out so as to give the more valuable species a chance.

The following table shows the comparative growth of the more promising species in this new plantation. All the trees were small, or from 10 to 15 inches high, when planted out in January, 1897. All were measured in May, 1902, when the age from seed was less than six years. This May measurement includes of course only a part of the 1902 growth. The trees selected are an average of the western half of the grove, which much better represents the entire mesa than the more gravelly eastern end.

EUCALYPTS IN MAY, 1902.

	Height.	Girth.
E. globulus	32 ft.	23 in.
E. acervula	30 "	22 "
E. muelleriana	28 "	20 "
E. rostrata	27 "	20 "
E. angulosa	25 "	18 "
E. andreana	25 "	17 "
E. tereticornis	23 "	19 "
E. goniocalyx	23 "	17 "
E. populifolia	22 "	15 "
E. cosmophylla	21 "	16 "
E. Foeld-Bay	21 "	14 "
E. stuartiana	20 "	16 "
E. cinerea	20 "	15 "
E. acmenoides	20 "	10 "
E. paniculata	18½ "	13 "
E. resinifera	18½ "	13 "
E. microcorys	18½ "	12 "
E. dicipiens	16 "	12 "
E. polyanthema	16 "	10 "
E. botryoides	14 "	11 "
E. jugalis	13 "	10 "
E. sideroxylon	9 "	9 "

This table is very suggestive. In 1898, *E. goniocalyx* had made a better showing than the blue gums, but it now ranks eighth. Every species in this list which stands over 15 feet high at present (nineteen species in all) is well worth further trial and planting on a larger scale, for the average annual rainfall since these trees were set has been but 8.8 inches, and for the first three years it was less than 7 inches. The only water ever received by any of these trees was about a quart each when planted, that being a very dry year. In ordinary seasons, that is, in seasons of ten or more inches of rainfall, even this slight irrigation would not have been needed.

The growth of *E. acervula*, *E. muelleriana*, *E. rostrata*, and a few others, as shown by the table, is especially striking. All the species listed in this table have made well-shaped trees. *E. cornuta*, *E. megacarpa*, *E. alpina*, and a few others of shrubby growth have only a botanic value here, but among those which have made strong growth are some extremely valuable timber trees, such as *E. rostrata* and *E. muelleriana*.

Enlargement of Collection.—When the University took charge of the substation in 1893, there were forty-four species of eucalypts growing here, as nearly as could be determined by the Botany Department.

Many of these were represented by only one or two specimens. At the present time there are something more than a hundred species here, many of them represented by fifty or more specimens of different ages and on different soils. All of these new species have been grown from

PLATE 13. E. SIDEROXYLON (VAR. ROSEA).

seed obtained from various botanical gardens, from Vilmorin & Co., Paris, or from the Department of Agriculture at Washington.

Among the newer sorts are a number of hybrids, which prove most interesting in their rapid growth and their promise of future value to

California. It is evident that crosses of the best eucalypts are likely to produce valuable results, giving possibly (*a*) finer and more free blossoming, and hence greater value for ornament and as honey-yielders; (*b*) better growth, more hardiness, or other economic advantages.

Among all the newer species, however, none are more striking in appearance than *E. ficifolia*, by far the most brilliant, medium-sized tree of the family. In some respects even more graceful and ornamental is the famous *E. sideroxylon* var. *rosea*, a superb, quite hardy, drought-resisting species of much larger growth than *E. ficifolia*. Its dark, red-brown bark, bluish foliage, and elegant, half-weeping branches, give it a distinguished appearance in any collection, and the largest specimen at the substation, a plate of which, made in 1896, is herewith shown, has increased in size steadily since that date. Younger trees make good growth and bloom early. There is no more promising species for general ornamental planting in southern California. *E. calophylla*, which has been widely planted, is a very showy species, but if *E. sideroxylon* var. *rosea* were more generally known it would probably take the lead.

The following periods of the eucalypts range over the entire year, and those who plant collections of these valuable trees never need be without blossoms. The following notes apply not only to Santa Monica, but also to the whole seacoast region south of Santa Barbara:

Months.	Species Usually Blooming.
January and February	Amygdalina, globulus, leucoxylon, occidentalis, polyanthema, robusta.
March and April	Amygdalina, diversicolor, eugenoides, leucoxylon var. rosea, marginata, meliodora, obliqua.
May and June	Citriodora, corynocalyx, diversicolor, eugenoides, gunni, obliqua, paniculata, rostrata, stuartiana.
July and August	Buprestium, calophylla, ficifolia, corynocalyx, "Sewell's Red," macrorhynchus, etc.
September and October	Alpina, calophylla, ficifolia, corymbosa, cornuta, lehmanni, etc.
November and December	Alpina, corymbosa, diversicolor, globulus, occidentalis, robusta, polyanthema, saligna, etc.

The New Grove of 1901.—There were some three hundred trees planted in January, 1901, at the northern end of the middle mesa. Their growth has been excellent, as shown by the following table. In a few cases measurements were again taken in May, 1902, to show the excellent spring growth, and these notes follow the table. These trees have received no irrigation since planting. Those from Department of Agriculture seed are indicated by the numbers in the second column of figures:

Name.	U. C. No.	Govt. No.	Size When Planted.	Size in Jan., 1902. Height.	Size in Jan., 1902. Girth.
E. incrassata	121	1652	15 in.	10 ft.	7 in.
E. rudis × rostrata	128	1672	16 "	8 "	8 "
E. botryoides × rostrata	130	1678	15 "	5 "	5 "
E. rostrata × resinifera	127	1670	18 "	8 "	8 "
E. maculata	119	1646	10 "	8 "	7 "
E. sp.	115	1635	16 "	6 "	5 "
E. stellulata	120	1651	8 "	6 "	7 "
E. longiflorus	105	1609	10 "	4 "	10½ "
E. pilularis	...	1657	8 "	5 "	7 "
E. macrocarpa	118	1644	12 "	6 "	5 "
E. raveretiana	125	1663	10 "	7 "	8 "
E. obtusiflora	122	1654	10 "	5 "	5 "
E. sp.	114	1633	12 "	6 "	5 "
E. pauciflora	108	1617	8 "	2 "	1½ "
E. macrandra	117	1643	8 "	1 "	½ "
E. sp.	116	1639	8 "	6 "	3 "
E. eximia	160	1625	8 "	6 "	3½ "

Name.	U. C. No.	Govt. No.	Size When Planted.	Size in Jan., 1902. Height.	Size in Jan., 1902. Girth.
E. punctata var.	164	----	12 in.	9 ft.	8 in.
E. salmonophloia	168	----	8 "	8 "	2½ "
E. sieberiana	170	1675	8 "	8 "	5 "
E. stricta	171	----	8 "	3 "	4 "
E. McArthurii	161	----	12 "	10½ "	8 "
E. robusta	---	1668	18 "	7 "	6 "
E. corynocalyx	---	1620	15 "	9 "	7 "
E. rubida	167	----	12 "	11 "	7½ "
E. stuartiana	36	1676	16 "	12½ "	8 "
E. pulverulenta	163	----	8 "	8 "	5 "
E. globulus	---	----	15 "	13 "	9 "
E. rostrata	20	----	15 "	9½ "	7 "
E. resinifera var. grandiflora	27	----	18 "	10 "	6 "
E. sideroxylon	9	----	18 "	7 "	5 "
E. tereticornis	29	----	12 "	8 "	5 "
E. redunca	165	----	6 "	12 "	½ "
E. obcordata	162	----	6 "	2 "	3 "

Notes on Eucalypts from the Department of Agriculture.—No. 1652, *E. incrassata*, the "Mallee" gum, increased 2 feet in height between January and May, 1902. This species stands up fairly well against the wind, but some specimens are crooked and poor.

No. 1672, *E. rudis* × *E. rostrata*, is more stocky than the preceding and promises good results. The permanent leaves show considerable variation in different plants, as if the type were not yet fixed.

No. 1678, *E. botryoides* × *E. rostrata*, known in France as *E. Trabuti*, is a very interesting tree. While slower in growth than many species, it is now gaining (growth from January to May, 1902, was 3 feet). The trees are remarkably uniform in appearance and incline to spread.

No. 1670, *E. rostrata* × *E. resinifera*, has also shown rapid spring growth, average plants girthing 1 inch more in May than in January and standing 2 feet higher. The *rostrata* blood shows very plainly in this cross. It is worthy of extended trials.

No. 1646, *E. maculata*, the "Morrel Gum"; No. 1617, *E. pauciflora*, the "White Gum"; No. 1616, *E. globulus*, the well-known "Blue Gum"; No. 1622, *E. crebra*, the "White Ironbark," and some others are already represented by large trees, as well as in the new plantations. The best young specimen of *E. globulus* measured May 1st was 17 feet high and girthed 12 inches.

No. 1635, received as "a species," is otherwise noted in the Inventory as *E. gracilipes*, which is said to resemble *E. leucoxylon*. It is a slow grower here, and does not as yet seem superior to *leucoxylon*.

No. 1633, also unnamed when received, is *E. gomphocornuta*. Its growth is practically identical with that of No. 1643 (*E. macrantha*), which is extremely poor. It evidently requires more rainfall and a heavier soil.

No. 1639, which came unnamed, but was inventoried as *E. jugalis*, a "small tree 25 to 30 feet high," is a very beautiful species, much resembling in tint, odor, and appearance a half-dwarf *E. globulus*. The plant is more graceful, and the first leaves somewhat more pointed. Its growth averages 6 feet, as against 15 feet for *E. globulus*. This species should have value for ornamental planting.

No. 1609, *E. largiflorens*, the "bastard box," a valuable timber tree, grows very slowly compared with other species. *E. pilularis*, the Blackbutt (No. 1657), does somewhat better, and *E. stellulata*, the "Green Gum" (No. 1651), exceeds by a trifle such species as *E. macrocarpa* and, *E. eximia* of the same age and under similar conditions. *E. raveretiana*, the "Gray Gum" (No. 1663), is considerably better in point of growth than any of these.

One of the most striking of the new eucalypts is *E. stuartiana* (No. 1676), also received from other sources. Trees of this, on May 1st, were 14 feet high and girthed 11 inches. *E. corynocalyx*, the noted "Sugar Gum" (No. 1620), grew 3 feet between January and May, and is also one of the best in appearance among the species in this plantation.

Other New Eucalypts.—Several species or sub-species, not heretofore named, have done very well. One of the very best of these is *E. punctata* var. *grandiflora*, of excellent upright and rapid growth. *E. resinifera* var. *grandiflora* is another of striking appearance. Both the above have made trees 12 feet high in fifteen months after planting out, and both, like *E. rostrata* and *E. corynocalyx*, are worth the serious consideration of planters. *E. rubida* has done nearly as well, and is also a desirable species. *E. McArthurii* yields badly to the sea winds. *E. stricta* has grown slowly and very poorly. *E. obcordata*, while very slow in growth, is a handsome shrub.

Distributions of Seed and Trees.—Eucalyptus seeds gathered at this substation were to some extent distributed locally. Trees of new and rare species to the number of 4,000 were distributed to such applicants as agree to make future reports. Among those receiving trees were the American Beet Sugar Company at Oxnard, the Hollywood Cemetery Association, the Imperial Land Company, Senator Thomas R. Bard, Mr. T. P. Lukens, Mr. Theodore Payne, and Mr. W. L. Clayberg. These trees were sent to widely scattered points, from Indio and Imperial to Santa Barbara and Antelope Valley. Many small lots of a dozen named trees were sent out. The number of species distributed was twenty-five, including *E. ficifolia* and other ornamental sorts, *E. corymbosa*, *E. polyanthema*, and other honey eucalypts, and *E. corynocalyx*, *E. rostrata*, and other timber and drought-resisting species.

Hillside Planting.—In 1901 and 1902 a number of eucalypts were planted on the newly-cleared hillslopes. In places these were too steep to plow and the trees were "pocketed in." The results have been very satisfactory, not one out of four hundred trees having been lost. Most of the species represented in the new plantation on the middle mesa were used here also, together with a few represented only on the upper mesa. In all, nearly thirty species were set on this slope. On similar slopes, pines (*P. insignis* and *P. austriaca*) and six species of acacias were planted at the same time and have made a good start. Each of these trees received a quart of water when planted out.

ACACIAS.

In previous reports attention has been called to the value of the tanbark acacias for otherwise waste lands wherever the winter temperature does not fall below 22° Fahr. A full account of the yield of eight-year-old trees of *Acacia decurrens*, *A. mollissima*, and *A. pycnantha*, together with analyses, appears on pages 227–230 of the Report for 1897–8. The remaining portion of the acacia grove therein reported upon suffered much from drought in 1898–1900, but the past two winters

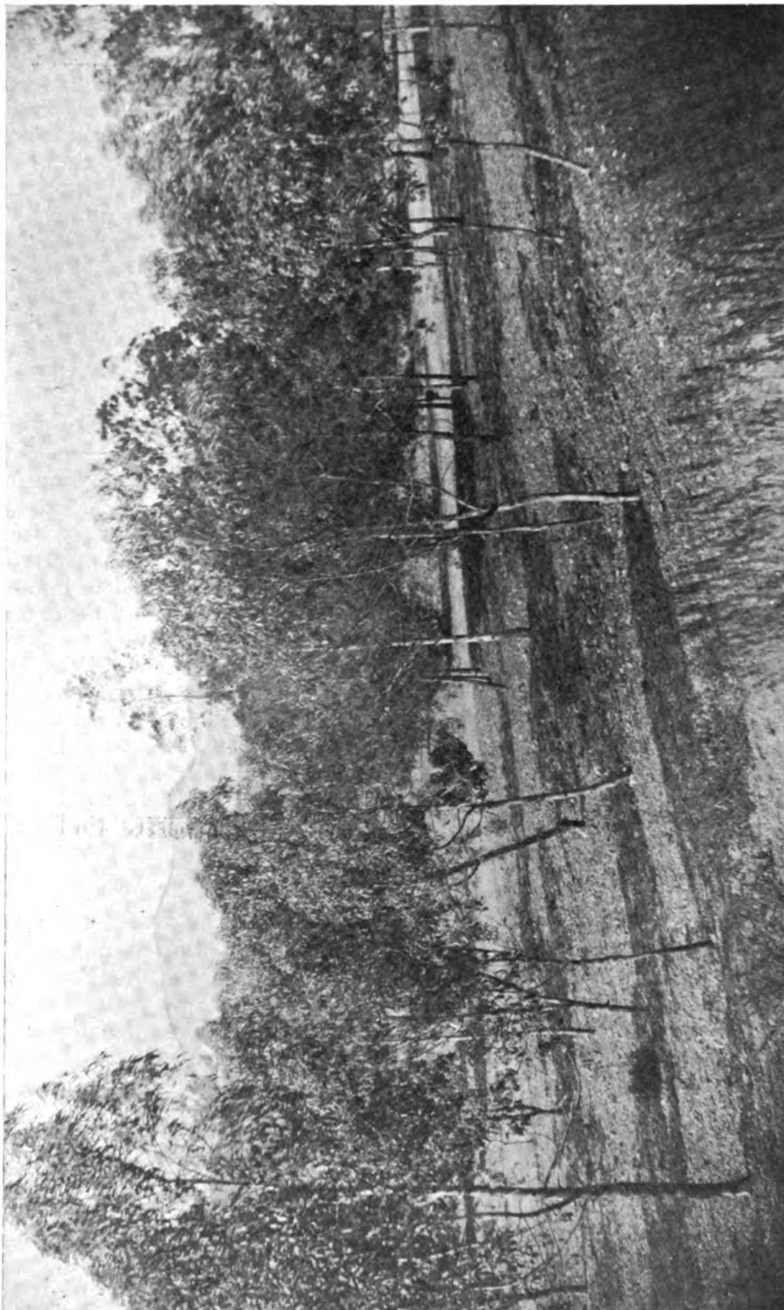


PLATE 14. ACACIA GROVE (*A. pycnantha* AND *decurrens*)—SANTA MONICA FORESTRY SUBSTATION.

have greatly aided it. Young trees planted out in the winter of 1901 and the present season have also done very well indeed.

Drought-Resistance.—All observations at the substation confirm the view that on the light, gravelly wash of the mesa, the large tanbark acacias stand the drought somewhat better than do the eucalypts. Seedling trees also frequently spring up in the grove. With good cultivation, a grove of *A. decurrens* or *A. mollissima* can be established in such soil without any irrigation and with an annual rainfall of only 10 inches.

The largest specimen of *A. decurrens*, now twelve years old, girths 3 feet 9 inches, measured breast-high; this surpasses both *A. mollissima* (largest tree, 2 feet 10 inches) and *A. dealbata* (largest tree, 2 feet 4 inches). *A. cyanophylla*, a low, shrub-like, much-branched tree, quite unlike the two preceding species, which rise to 40 and 50 feet, has in the case of the largest specimen a trunk girthing 3 feet 1 inch. All these stand on soil similar to that of the older eucalypts and have suffered less in times of drought.

Acacia melanoxylon, whose beautiful rosewood-like timber only needs to be better known to be demanded among cabinet-makers, has now, in 1902, fully recovered from its severe suffering in the years of drought, when one half of the large trees of this species ceased growth and some died. This recovery when the annual rainfall rose from about 6 inches to nearly 12 inches is interesting, but the profitable growth of this riverine species for timber is evidently limited to regions of more rainfall and better soil. Nevertheless, the largest standing tree of *A. melanoxylon*, aged twelve years, girths 3 feet 8 inches.

The rapidity of growth of *A. melanoxylon* is hardly surpassed by any other species, and it reproduces itself freely from root-cuttings or suckers as well as from seeds. One large tree removed in 1899, because it died in the ground, threw up a multitude of suckers scattered over a large area. Nine of these have been left at spaces of from 10 to 20 feet apart; they average a height of 18 feet and a girth of 15 inches. Fed, of course, by the old roots, this growth far surpasses that from seeds. In suitable locations, however, a wood-lot of *A. melanoxylon* could be trusted to reproduce itself from the roots. The fuel value of the wood is high.

Other Acacias.—A new collection of acacias was planted out in the spring of 1901, and with previous plantings and a few set in the spring of 1902, the total representation of acacias is now nearly thirty species. One of the most striking of these is *A. Baileyana*, a very ornamental tree. *A. verticillata* and *A. linifolia*, both species of small growth, have attracted much attention.

OAKS AND OTHER HARDWOOD TREES.

English Oak (*Quercus robur*).—The English oak has now received a thorough test here on all the levels. Many trees promised well until about 1897. The largest, twelve years planted, now girth from 14 inches to 21 inches, a foot from the ground, and this would be excellent if the trees were healthy. But four out of five of the trees this age are dead or dying at the top. A few are 16 feet high; the tallest healthy tree is but 13 feet. The growth is seriously affected, as elsewhere on the coast, by the little "oak wasp" (*Andricus* sp.), and the whole tendency of the tree is to grow shrubby and crooked. It has taken much pruning and suckering to keep them in shape. The tree is therefore practically useless here for timber purposes, as are all the oaks tested at this substation.

The Japanese species need better soil and more water; the Eastern oaks grow very slowly indeed. In the cañon the native coast live oak (*Quercus agrifolia*) grows very well, and there are some good trees of this species on the substation tract. Its growth is checked by caterpillars.

Black Locust.—This well-known tree remains the leading small hardwood adapted to this climate. It thrives on the middle mesa without irrigation, and reproduces readily from self-sown seed. Few trees have stood the severe droughts better. Trees can be grown here with trunks of 8 or 10 inches in diameter in twelve years. This tree in recent years has been much neglected; its value for fuel and fence-posts, as well as for various hardwood uses, justifies more general planting.

The Casuarinas.—No species of hardwood trees have proved more drought-resistant here than the larger casuarinas. *C. suberosa* is one of the best. *C. glauca* has done well. The largest trees of *C. suberosa*, now twelve years old, show trunks 6 feet to lowest branches and girthing from 2 feet 2 inches to 2 feet 10 inches. Such growth gives evidence of the great value of casuarinas to tree-planters.

Zelkova keaki.—This Japanese hardwood tree needs more rain; otherwise, the climate is well adapted to its growth. It develops, however, too slowly in California to be of value anywhere when compared with other species of hardwoods.

Ashes.—After long trial of five species, including the European White, American White, etc., the Arizona ash (*Fraxinus velutina*) proves by far the best for this locality. So well does it grow from seed that a plantation, if rainfall or irrigation up to an average of 15 inches per annum can be obtained, should be profitable. Here, with an average of only 10 inches, the tree, though making a good start, does not equal the common black locust, the casuarina or the best acacias; but it is exceedingly drought-resistant.

Maytenus boaria.—This little Chilian hardwood tree has taken hold remarkably here, growing fast without irrigation. Its value for ornamental purposes is undoubted, but its hardwood value depends on rate of growth, which is greater here than at Berkeley, with greater rainfall.

Other Hardwood Trees.—There are many interesting and valuable trees in the arboretum here which have proven their adaptation to the locality, and some of these deserve especial mention.

Seed of the *Schinus terebinthifolius*, a new and large-leaved pepper tree, was locally distributed last season. The demand is great and increasing. It is a much more bright-leaved, healthy, and attractive tree than the common pepper tree (*Schinus molle*), and should in great degree supersede it. As in the case of the common species, the berries are red and handsome; the leaves and general growth are superior. It was planted on a dry hillside and has received no irrigation.

CHICO FORESTRY SUBSTATION.

(Situated one mile east of Chico, near the Sierra foothills; elevation, 230 feet.)

In previous reports the history of this substation has been given, and need not be repeated. Three years' further experience with the location only makes more evident its great value as regards soil, climate, and facilities for the cheap and rapid production of fine forest trees, or for any agricultural experiments.

Five acres as yet unplanted remain at the western end of the tract, and the soil there is extremely rich. The vacant land at the upper or eastern end of the tract is more sandy, though still excellent for tree growth.

Since 1898 the substation has been carried on at a reduced expense, using the Rancho Chico teams and labor and paying merely the actual cost. A workman has occupied the small house on the grounds and has kept the place in order, working elsewhere when not needed at the substation. In 1901, Mr. T. L. Bohlender, formerly in charge of the Chico nursery and later the ranch foreman, made an agreement by which he gives a portion of his time to supervision of the work at the substation, and this arrangement continues.

The substation, however, needs the entire time of some competent person, as at Santa Monica, or it might with advantage be developed hereafter into a substation fully equal in importance to that near Pomona, for not less than five acres of its area can be devoted to agricultural experiments without seriously infringing upon its forestal value. Besides, it is probable that a larger area can be secured when needed for strictly forestry work. At all events, the foundation for a most useful Sacramento Valley substation exists at Chico, where also sufficient trees can be easily and cheaply grown to cover the entire eastern or hill portion of the University tract at Berkeley.

There have been no other changes in local management. Mr. V. C. Richards, editor of the Chico "Record," appointed Patron in 1897, still holds that office. Colonel C. C. Royce, manager of Rancho Chico, and Mrs. Bidwell, the owner of that famous place, have continued their interest in the station.

Eucalyptus Planting.—The most important extension planned for is that of the eucalypts at the eastern end of the tract. About four thousand trees of *E. rostrata* and other hardy species are being grown for planting here in the autumn of 1902. They are now in seed-boxes and will be set out with the first rains.

CLIMATIC CONDITIONS.

There is very little difference in climate between the town of Chico and the substation. Some seasons the cold is less at the latter place, but severe frosts are about the same everywhere along the creek. In fact, some of the orchards which have suffered most are several miles east of Chico, and at a considerable elevation. Only a few species of acacias do well here, and the eucalypts are also limited in their adaptation to this region. The growth of the conifers is enormous, and that of many oaks and ashes is also unusually great. The rainfall is excellent; the summer heats are modified by the trade winds.

Rainfall.—The average rainfall of the Chico district, based on observations since 1870, is somewhat over 25 inches. It has fallen as low as 12 inches, and has risen to more than 50 inches, but these extremes very rarely occur. The following table shows the rainfall for the past seventeen years, the average of which, disregarding 1901–2, which is not quite complete at this date, is 26.64 inches:

RAINFALL FROM SEPTEMBER, 1885, TO APRIL, 1902.

Season.	Total Rainfall.	Period in which Some Rain Fell.
1885–6	31.13 in.	7 months 12 days.
1886–7	17.16 "	7 " 28 "
1887–8	14.49 "	7 " 12 "
1888–9	21.50 "	9 " 11 "
1889–90	52.71 "	7 " 5 "
1890–1	23.46 "	9 " 10 "
1891–2	22.40 "	7 " 12 "
1892–3	33.50 "	7 " 10 "
1893–4	23.32 "	10 " 4 "
1894–5	34.56 "	7 " 28 "
1895–6	25.54 "	7 " 1 "
1896–7	22.44 "	9 " 20 "
1897–8	12.81 "	7 " 2 "
1898–9	18.45 "	6 " 5 "
1899–1900	24.89 "	7 " 1 "
1900–1	27.22 "	7 " 22 "
1901–2	19.96 "	7 " 22 "

There is a good deal of early summer rain in this region, lengthening the season. The rains have commenced as early as August 30th, but the usual time is in late September or early October. They have continued until July 11th, in showers after April, excellent for many crops, but injuring cherries, hay, etc. The rainless period is comparatively short here, and the growth of all kinds of trees suitable to the climate is therefore stimulated. No other portion of California with which I am acquainted has shown such rapid growth of the native white oak (*Quercus lobata*), nor such large groves of second-growth trees springing up since the American occupation, and this must be attributed in great measure to the favorable rainfall.

Temperature.—The observations of the past twenty years give an average winter temperature of 46.6° Fahr., an average summer temperature of 81.3°, and an average annual temperature of 63.8°. The lowest temperature of the period was 18°, and the highest was 115°.

The following table shows the temperature day by day during 1899, 1900, and 1901, as furnished by Colonel C. C. Royce, and kept on Rancho Chico. These temperatures were taken from a point fifteen feet above the ground, and the minimums therefore show from 5° to 8° lower than would be the case if taken in the town, on the plan of the Weather Bureau, from the top of a high building. They were taken for agricultural purposes, and show the actual conditions to which vegetation at the forestry station and the adjacent district is subjected:

TEMPERATURE RECORDS AT RANCHO CHICO.

	1899.		1900.		1901.	
January.						
Temperature—						
Mean for month (Fahr.)		53°		48°		44.9°
Warmest day	27th	75	6th, 17th	62	16th	62
Coldest day	4th	29.5	24th	30	1st	23
Range		45.5		32		39
Greatest daily variation	24th	31	9th	23	19th	29
Least daily variation	18th	5	28th	3	2d	6
Mean daily range		17.5		11.4		17.2
Mean lowest		46		42		36
Mean highest		59		54		53.9
Frost on	8th, 12th, 23d, 24th.		9th, 10th, 11th, 25th.		7th, 15th, 16th, 23d–26th, 28th.	
Rain on	6th. 7th, 9th–11th, 13th–15th.		1st–5th, 12th–15th, 18th, 28th.		3d, 4th, 6th, 8th, 10th–14th, 20th, 21st, 24th, 31st.	
Fog on	17th, 18th.		12th–15th, 18th–22d, 29th–31st.		13th, 14th, 29th, 30th.	
Ice on			24th.		1st, 9th, 10th, 17th, 19th, 29th.	
February.						
Temperature—						
Mean for month		51		50.8		48.5
Warmest day	19th	79	24th	70	28th	77
Coldest day	6th	24	7th, 9th	33	10th	26
Range		55		37		51
Greatest daily variation	18th	31	23d	31	10th	32
Least daily variation	28th	7	7th	2	5th, 13th	8
Mean daily range		23.7		19.3		18.9
Mean lowest		39.1		39.8		39.1
Mean highest		63		60.7		58
Frost on	10th, 11th, 25th.		5th–7th, 9th, 11th, 12th, 23d, 27th, 28th.			
Rain on	28th.		1st, 2d, 17th–20th, 25th.		2d–5th, 7th, 13th, 16th, 18th–20th.	
Fog on			2d, 3d.			
Ice on	4th, 5th, 6th.		Hailstorm, 18th.		1st, 6th, 10th, 11th. Snow on 7th, 8th.	
March.						
Temperature—						
Mean for month		53.8		57.3		54.9
Warmest day	6th	74	13th	81	5th	78
Coldest day	10th	30	28th	33	31st	34
Range		44		48		44
Greatest daily variation	6th	35	28th	36	19th	33
Least daily variation	15th	3	7th	4	4th	3
Mean daily range		20.4		23.4		23.4
Mean lowest		43.6		45.5		42.2
Mean highest		64		69.1		67.5
Frost on	10th, 13th, 30th.		28th.		8th, 13th–15th, 28th–31st.	
Rain on	7th, 8th, 12th, 14th, 15th, 17th, 19th–20th, 22d–24th, 31st.		3d, 4th, 6th–8th, 19th.		9th, 10th, 22d, 25th, 27th, 28th.	
Ice on	13th.		Hail, 4th.			
April.						
Temperature—						
Mean for month		59.9		57.3		55.9
Warmest day	21st	87	17th, 18th	81	13th	81
Coldest day	29th	36	9th	35	4th	30
Range		51		46		51
Greatest daily variation	29th	39	17th	36	10th	40
Least daily variation	23d	14	11th	3	5th	3
Mean daily range		28.2		23.7		25.2
Mean lowest		45.8		45.2		41.7
Mean highest		74		69.3		70.1

TEMPERATURE RECORDS AT RANCHO CHICO—*Continued.*

	1899.	1900.	1901.
April—Continued.			
Frost on	24th, 25th, 28th, 29th.	9th.	3d, 4th, 6th-10th, 22d.
Rain on	24th, 30th.	1st, 2d, 6th, 11th, 12th, 19th-21st, 30th.	2d, 5th, 28th, 29th.
May.			
Temperature—			
Mean for month	62°	64.8°	63.7°
Warmest day	10th ... 96	31st ... 92	31st ... 92
Coldest day	1st ... 38	11th, 27th ... 44	19th ... 41
Range	58	48	51
Greatest daily variation	12th ... 39	20th, 30th ... 26	8th ... 38
Least daily variation	31st ... 14	4th ... 16	24th ... 13
Mean daily range	27.5	28.3	27.2
Mean lowest	47.9	51.8	50
Mean highest	75	77.7	77.4
Frost on	1st, 2d, 15th.		
Rain on	23d-25th, 28th, 31st.	1st, 3d-5th, 9th-12th.	1st, 24th, 25th, 27th. Fog on 29th.
June.			
Temperature—			
Mean for month	74.5	70.4	71.2
Warmest day	16th ... 104	6th, 11th ... 102	28th ... 103
Coldest day	2d ... 46	16th ... 48	12th ... 44
Range	54	54	59
Greatest daily variation	16th ... 44	5th ... 43	13th, 27th ... 38
Least daily variation	1st, 24th ... 15	21st ... 16	4th ... 21
Mean daily range	30.1	30	30.5
Mean lowest	59.8	58	55.2
Mean highest	89.3	82.8	87.1
Rain on	1st, 18th, 24th.	15th, 21st.	
July.			
Temperature—			
Mean for month	77.7	78.7	78.6
Warmest day	18th, 19th ... 105	7th, 8th ... 104	6th, 27th, 31st ... 101
Coldest day	6th ... 52	2d ... 54	2d, 13th ... 52
Range	53	50	49
Greatest daily variation	8th ... 41	7th ... 44	19th, 20th ... 41
Least daily variation	29th ... 18	22d ... 22	11th ... 12
Mean daily range	33.5	30.5	32
Mean lowest	60.8	62.6	62.7
Mean highest	94.5	94.9	94.4
August.			
Temperature—			
Mean for month	72.2	72.2	75.1
Warmest day	1st, 30th ... 92	1st, 3d ... 99	2d ... 104
Coldest day	27th, 28th ... 49	21st ... 51	22d ... 49
Range	43	48	55
Greatest daily variation	1st ... 38	1st ... 42	11th ... 39
Least daily variation	17th ... 17	6th ... 20	17th ... 8
Mean daily range	29.2	29.6	29
Mean lowest	56	56.4	59.4
Mean highest	88.3	88	90.8
Rain on	3d, 4th, 6th.		
September.			
Temperature—			
Mean for month	72.7	64.5	66.7
Warmest day	24th ... 99	1st ... 94	14th, 15th, 16th, 17th ... 92
Coldest day	6th, 7th ... 47	27th, 30th ... 44	24th ... 42
Range	52	50	50
Greatest daily variation	23d ... 44	1st, 29th, 30th 36	8th ... 37
Least daily variation	28th ... 25	8th ... 8	23d ... 10
Mean daily range	35.2	26.3	27
Mean lowest	55	52	53.4
Mean highest	90.3	79	80
Rain on		11th, 12th.	22d, 23d, 25th.

TEMPERATURE RECORDS AT RANCHO CHICO—*Continued.*

	1899.	1900.	1901.
October.			
Temperature—			
Mean for month	58.8°	58.3°	65.2°
Warmest day	8th ... 96	8th ... 82	12th ... 89
Coldest day	15th, 24th ... 37	30th ... 35	29th ... 41
Range	59	47	48
Greatest daily variation	6th ... 41	8th ... 36	11th, 12th ... 36
Least daily variation	20th ... 5	4th ... 7	26th ... 12
Mean daily range	23.9	23	25.4
Mean lowest	46.8	46.8	53.2
Mean highest	70.8	69.7	77.1
Frost on	24th, 27th.	25th.	
Rain on	10th, 12th, 13th, 19th–22d, 29th, 30th.	2d, 3d, 4th, 11th, 18th, 19th, 27th, 30th, 31st.	17th, 23d, 25th–28th.
November.			
Temperature—			
Mean for month	53.9	52.9	54.4
Warmest day	13th, 14th ... 69	12th ... 74	3d ... 74
Coldest day	22d ... 36	28th, 29th ... 35	12th ... 36
Range	33	39	38
Greatest daily variation	2d ... 31	11th ... 31	4th ... 31
Least daily variation	11th ... 9	24th ... 5	19th, 23d ... 5
Mean daily range	18.5	19.3	19
Mean lowest	44.6	42.5	44.9
Mean highest	63.1	63.3	63.8
Frost on	23d.	28th.	11th, 12th.
Rain on	3d, 8th, 9th, 11th, 12th, 15th, 16th, 18th, 21st, 23d, 25th–29th.	7th, 15th, 16th, 17th, 19th, 20th, 21st, 24th, 25th, 30th.	9th, 15th, 16th, 19th, 20th, 23d, 28th.
Fog on		1st, 23d, 27th, 29th.	
December.			
Temperature—			
Mean for month	48.1	45.7	46.8
Warmest day	2d, 3d ... 64	21st ... 66	2d ... 68
Coldest day	20th ... 28	31st ... 23	16th ... 26
Range	36	43	42
Greatest daily variation	1st ... 24	27th, 28th ... 25	20th, 31st ... 30
Least daily variation	11th ... 6	10th ... 3	3d ... 1
Mean daily range	15	12.7	19.5
Mean lowest	44	39.1	37
Mean highest	52.2	52.2	56.5
Frost on	1st, 6th, 17th, 18th.	1st, 23d, 27th.	7th, 22d, 26th, 28th.
Rain on	4th, 7th–11th, 14th–16th, 29th–31st.	12th, 14th, 16th–20th.	2d, 3d, 5th, 9th.
Fog on	3d, 4th, 20th–29th.	2d–13th, 25th, 26th, 29th.	
Ice on	13th, 19th, 20th.	28th, 30th, 31st.	11th–21st, 29th.

STUDIES OF TREE GROWTH.

The fitness of this district to rapid growth of trees is illustrated by almost every measurement taken since the establishment of the station. Cultivation has been given to all the trees when small. The larger conifers now cover the ground so completely that cultivation is no longer necessary or practicable.

THE CONIFERS.

The most striking feature of the substation consists of large pines, cypresses, sequoias, and other conifers planted in blocks. The following table shows the comparative growth of a few species:

TABLE I. Representative Conifers.

Name.	No. of Trees Measured.	Av. Size, Oct., 1897.		Size, Oct., 1901.	
		Height.	Girth.	Height.	Girth.
Araucaria Bidwelli	1	12 ft.	6 in.	20 ft.	8 in.
Chamæcyparis Lawsoniana	5	18 "	22 "	21 "	30 "
Cupressus sempervirens	5	26 "	18 "	42 "	36 "
Pinus austriaca	5	18 "	16 "	22 "	21 "
Pinus insignis	5	25 "	28 "	32 "	42 "
Pinus resinosa	5	22 "	17 "	38 "	36 "
Pinus sylvestris	5	16 "	14 "	21 "	24 "
Pseudotsuga taxifolia	5	11 "	8 "	16 "	15 "
Sequoia gigantea	5	27 "	36 "	42 "	48 "
Sequoia sempervirens	5	22 "	16 "	43 "	46 "

These trees are in age fourteen or fifteen years from seed, but no record was kept at the station by those in charge before the University assumed control. There is but one *Araucaria*, and it stands too close to large oaks to have a fair chance. The numbers of the other species range from 10 (*Pseudotsuga*) to 400 and 500 (*Pinus sylvestris* and *Cupressus sempervirens*). The trees chosen stand on the outside of the blocks which are now being thinned.

The only difficulty in regard to the continued development of these blocks of conifers and the maturing of as large a timber-crop as this soil can possibly carry, lies in the nature of some of the root systems in transplanted trees. When a block of 225 trees of *Pinus resinosa* was partially thinned in the spring of 1902, a violent gale from the north blew down several of the standing trees, and showed conclusively that the roots of conifers planted in sacks, as these were in 1889, are more or less prevented from properly descending. There is no reason why much smaller conifers should not be used, or seeds sown under temporary shelter plants. In all cases where deep-rooted, healthy trees are desired, pines and other conifers can be transplanted from boxes when only a foot high, in small "puddled" balls of earth, without the use of sacks. Certainly the sacks should always be removed, not merely slashed across.

Self-sown seedlings already show in the groves, and the reproductive powers of any natural forest in this district, if properly protected, are evidently great. Allusion has been made to the rise of large oak groves, but no less interesting is the extent to which young *Pinus sabiniana* thickets abound on Rancho Chico. This forestry station shows on every hand satisfactory natural increase of many species, coniferous and deciduous.

Further Notes on Conifers.—There were two cedars, *Cedrus deodara* and *Cedrus Libani*, planted in 1895 at the eastern end of the substation. The former has far outgrown the latter, and is 23 feet high, with branches touching the ground; the latter is but 13½ feet high.

The Italian cypresses (*C. sempervirens*) are in some cases nearly 50 feet high, and are superb trees. Many are heavily branched, and the lower branches in these blocks begin to fall, but the columnar specimens still receive light on all sides.

The best block of *Pinus austriaca* averages over 25 feet high, with girths that often equal or exceed 20 inches, but the specimens tabulated were from a block of somewhat smaller size.

The growth of conifers in the mixed forest planted in January, 1895, affords the best illustration the substation can give of the ease and rapidity of tree-growth here. The conifers are rapidly taking possession of the entire ground, and the larger maples, walnuts, catalpas, paulownias, and mulberries scattered through this two-acre plantation have been removed, leaving, however, many deciduous trees. All the conifers here were planted out when small by Mr. Boland, then foreman, and have deep root-systems.

The most remarkable growths made in the mixed forest were of *Pinus sabiniana*, many of which now stand more than 18 feet high. Three measured girths of 20, 22, and 23 inches. From seed these are but eight years old. It is a pity that the timber from this tree is not more valuable, but its usefulness in the foothills has hardly received sufficient attention, for it grows under very adverse conditions. The following brief table shows comparative growths of some of the mixed-forest conifers:

TABLE II. MEASUREMENTS OF CONIFERS IN MIXED FOREST.

Name.	No. Measured.	Age.	Height.	Girth.
Pinus sabiniana	5	8 to 9	18 ft.	21 in.
Pinus ponderosa	5	8 " 9	12 "	10 "
Pinus austriaca	5	8 " 9	11 "	9 "
Pinus lambertiana	5	8 " 9	10 "	8 "
Thuya gigantea	4	8 " 9	9 "	7 "
Larix europea	2	9	4 "	3 "

Conifers of Especial Value.—The experience of the substation leads us to recommend several species of conifers for more general planting in the Sacramento Valley and on the foothills. Among our native trees, *Pinus ponderosa*, the great yellow pine of the Sierra takes a prominent place. The redwood (*Sequoia sempervirens*) does much better than was expected, but on drier situations will not thrive so well. The growth and health of the Big Tree (*Sequoia gigantea*) shows that it may be extensively planted for ornament and shelter. The Monterey pine, though growing quite well, is best adapted to the coast; but the so-called Oregon pine (*Pseudotsuga*) is entirely at home here. The best exotic conifers tested are the Deodar cedar and *Pinus austriaca*. The latter is not as rapid in growth as some other species, but it makes a fine tree. There should be more attention paid by land-owners to the establishment of small groves of our native conifers, especially as windbreaks.

DECIDUOUS TREES.

The largest *European White Birch* among several of the same age, girths 30 inches and is 45 feet high. Its age is about fifteen years. A group of about seventy-five younger specimens of this birch (*Betula alba*), planted in 1895, small trees received by mail, are now (1902) from 35 to 40 feet high, and four girthed, respectively, 12, 14, 15, and 16 inches. Birches generally do well in this region, and any one who wishes may have a grove of this beautiful white-stem tree, the fastest-growing species of birch yet tested here.

Previous reports have described the two *Catalpa* (*C. speciosa*) groves. Small trees from self-sown seeds are frequently to be found here. The late General Bidwell planted many catalpas and distributed trees widely at various times from his nurseries. The average height of the catalpas at the substation in 1897 was 30 feet, with trunks 26 inches in girth, breast-high. In 1902, three girthed 36, 40, and 46 inches. Young catalpas planted in 1895, when 3 feet high, are now (1902) 18 feet high and girth 12 inches. The catalpa seems to produce on a given area in a given time about twice the amount of wood as does the well-known Western box-elder (*Negundo Californica*), which is often planted for its rapid growth. Neither species, however, begins to yield as much wood as the paulownia.

The *Paulownia imperialis* of Japan is very little known, but it grows with such rapidity here that its more frequent growing can be recommended. Some remarkable measurements of this tree have been given in previous reports. This year (1902) one was measured which in two years had grown from an old stump to a height of 25 feet with a girth of 15 inches and was well-branched about 15 feet from the ground. Numbers of the older paulownia planted in 1889 are over 40 inches in girth; three, measured "as they came," were 45, 48, and 49 inches. One of the largest, near the grove of sequoias, girths 5½ feet. The commercial value of paulownia wood in California has not yet been determined, but many small articles of Japanese manufacture, such as toys, boxes, and furniture, are made of this light-brownish timber.

Several species of *Celtis* (nettle-tree) have grown very fast here. The best is *Celtis australis*, which, planted in 1896, now girth 12 and 14 inches and are 16 to 18 feet high. *C. occidentalis*, somewhat older, has also made very fine growth. *C. orientalis* is much behind the others. These are all trees of easy cultivation.

One of the disappointments here is the growth of *Zelkova keaki*, which ranks as the best hardwood of Japan. A lot of trees were obtained in 1895 and several thousand trees grown. These were widely distributed, and a block was planted here. The trees have never straightened up or made much growth. The increase of wood is only about one quarter that of American ash and half that of English oak. The tree does no better anywhere else, so far as tested in California.

The *Ashes* have deservedly attracted attention here, and no other hardwood better justifies planting for timber in this region, if the best species be used. *Fraxinus dimorpha* is small and slow of growth, but a beautiful ornamental. It comes from Algeria. Trees planted in 1896 are now (1902) 10 and 12 feet high, girthing 7 and 8 inches. *Fraxinus kabyla*, also from Algeria, is a much more striking species. Four measured (eight years from seed) girthed 16, 18, 19, and 20 inches, and they are 18 to 20 feet high, with fine trunks. *Fraxinus oregona*, of the same age, are only two thirds as large. *Fraxinus viridis* is also much poorer than *F. kabyla*. *Fraxinus alba*, however, the well-known American white ash, ranks in point of growth somewhat nearly with *F. kabyla*. Trees grown from seed in 1892 are now, ten years later, about as large as *F. kabyla* trees of eight years of age, and a few are even larger. The difference so far is perhaps ten per cent in favor of the foreigners. The older white ashes, in some cases, fourteen years of age, are very fine trees. One is 40 feet high and 3 feet in girth, and all are nearly as large as this. The best single ash upon the substation, considering age, is a white ash eleven years old, planted on the main avenue. It is 30 feet high, 10 feet to the lowest branch, and girths 28 inches. The growth of ash timber on such land as this should attract attention, as evidently in twenty or twenty-five years some cutting could be done. The growth of the white and the Kabyla ashes here has been about equal to that of.

the strong-growing Japanese mulberry known as "Lhoo," and much surpasses that of the white or red mulberries.

Elms are often planted in this region. Two Huntingdon elms at the west gate, planted from the nursery in 1892, now girth 31 and 35 inches,

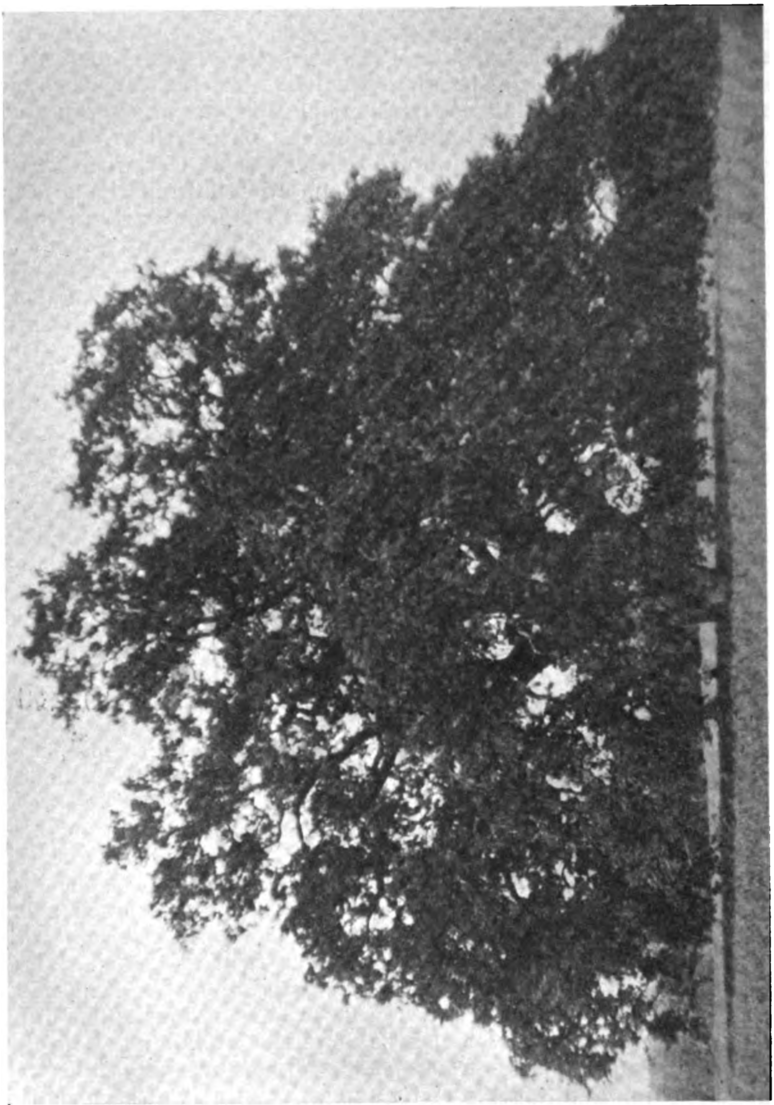


PLATE 16. THE HOOKER OAK, ON RANCHO CHICO, ONE MILE FROM CHICO FORESTRY SUBSTATION.

and have a very large spread of branches. They were in full bloom March 29, 1902.

English Oaks are well represented here, as well as many other species of *Quercus*. All have been planted since 1894, and many now bear acorns. Those left untrimmed are "bushy," branch near the ground, and are far behind those that were pruned. The latter, now from seven to nine years old from the acorn, stand from 14 to 15 feet high, with trunks that girth from 8 to 15 inches. One tree, which was several years old when sent to the station, and is therefore about twelve years from the acorn, stands 22 feet high, with a trunk circumference of 21 inches. This region is one of the best oak districts in the State, and English oaks (*Q. robur*), or cork oaks (*Q. suber*), or any other desirable American or European species, can be grown here.

Quercus lobata has an excellent representative in the celebrated Hooker oak, which stands in the center of a large open glade, about a mile from the substation. This very shapely and beautiful tree, shown in the accompanying illustration (taken by Dr. Loughridge in 1900), was greatly admired by Sir Joseph Hooker when in California. The following are the dimensions as measured in July, 1894, by Mr. Boland, the foreman of the station:

Circumference of trunk	20 feet.
Circumference of largest branch	15$\frac{1}{8}$ "
Spread of limbs from trunk, on south	73 "
Spread of limbs from trunk, on north	63 "
Spread of limbs from east to west	112 "
Approximate height	100 "

The largest willow trees, *S. salmoni*, or *S. alba salmoni*, grown from cuttings planted in 1895, are over 60 feet high, and girth more than 30 inches. One of these trees is 68 feet in height, and its trunk is 38 inches around, measuring breast-high. Cuttings of this willow have now been widely distributed; it grows considerably faster than the common *Salix alba* form.

THE EUCALYPTS AND ACACIAS.

Previous reports have described the work done with many sorts of eucalyptus here. Their rapidity of growth is astonishing, and it would seem that profitable plantations of certain species could be planted in the Sacramento Valley.

The station recommends *E. rostrata* and *E. viminalis* as highly desirable species, whose timber is much more useful than that of *E. globulus*. Few large trees of *E. rostrata* exist here, the earlier plantings having been mainly of *E. viminalis*, but a few are scattered in the earlier plantation (established in 1889), and there is no appreciable difference in the growth of the two species. Both are desirable; the wood of *E. rostrata* is considered the more useful.

The following measurements of the older trees, now thirteen or fourteen years from seed, will show how the red gums have increased in this kindly soil and climate. In the old grove, five trees out of twenty-one of *E. viminalis* were measured, and girthed, respectively, 46, 48, 51, 57, and 61 inches. One girthed almost exactly 6 feet. These trees are 20, 30, and 40 feet to a branch. Trees of *E. rostrata*, of the same age, girthed 50, 52, 54, and 64 inches, and one was a little more than 6 feet around.

A superb grove of mixed species, *rostrata*, *viminalis*, *amygdalina*, and others, averages trees of 50 to 60 inches in girth and something over 100 feet high. The largest tree here is 6 feet 6 inches in girth. Many of these stand 8 x 8 feet apart, but the grove is long and narrow, receiving light on all sides.

The hardy species of eucalyptus of the newer sorts are *E. alpina*, *E. acerbula*, *E. leucoxylon*, and the superb *E. Foeld-Bay*, seed of which was received from Vilmorin in 1895. This last named is by far the best of all the new eucalypts. Planted out in 1896, when quite small, it girths 31 inches in 1902, and bids fair to outgrow both *E. rostrata* and *E. viminalis*.

Acacias.—The well-known *A. decurrens*, which suffered much from frost here while small, has made large trees at last, several being now 53 feet high, with trunks that girth nearly 5 feet. *A. melanoxylon* has never suffered seriously from frost.

CENTRAL EXPERIMENT STATION.

Berkeley, Alameda County.

TREE-PLANTING ON A BERKELEY HILLTOP.

BY C. H. SHINN.

A significant experiment in tree-planting has been carried on for a number of years on a high hill-top in the northeastern part of the University tract at Berkeley. This tract comprises 249 acres (outside of the Hillegass tract) and rises, at first gradually, then more abruptly, from its western frontage on Oxford street to an elevation of 950 feet near the extreme northeastern corner. Its general appearance is familiar to the public, as a contour map has been printed on many occasions. It is sufficient to say here that the mountainous portion east of the building site contains about 125 acres, used as pasture land.

The soil is for the most part adobe; the native vegetation, confined to the cañons, consists of coast live-oaks, laurels, willows, and lesser shrubs. One stray madroño stands on the creek near the agricultural building.

Eucalypts.—Considerable planting of eucalypts (chiefly *E. globulus*), pines (chiefly Monterey), and other conifers was done soon after the University was established here, but nearly all on a level below 400 feet, where the soil was deep and could be easily plowed. The growth of these trees has been rapid, and, in many respects, surprising. One large block of almost two thirds of an acre, situated west of the cinder track at the union of the two creeks, has long been recognized as one of the most instructive eucalyptus groves of its size in this part of California (see Plate 17). There are about two hundred and fifty trees here, the largest of which now girths 7½ feet, breast-high.

The trees on the outer edge of this grove range from 40 to 90 inches in girth, stand 8 to 10 feet apart, and often rise 40 feet without a branch; in the middle of the grove the trees are from 18 to 30 inches in circumference, but with even taller shafts. It is estimated that this grove, if cut for fuel, would yield about 400 cords of firewood, or at the rate of about 600 cords per acre.

One eucalyptus tree cut on the Hillegass tract in 1901 was measured by the writer. Its age was twenty-four years and its diameters were 26 inches and 31 inches after the bark had been stripped off. Yields of 800 cords to the acre have been reported from trees of twenty years of age. Ten-year-old red gums grown by Mr. J. C. McCubbin, of Reedley, yielded at the rate of 235 cords of wood per acre, and it was by him reported to have from 85 to 90 per cent of the fuel value of mountain live-oak. (Whether this was *E. rostrata* or *E. viminalis* was not reported.)

On the hills, where the soil is scantier, the rainfall of less amount, and trees more exposed to winds, the growth is necessarily very much less than it is on the flat. Such hill land as this, however, has only a pasture value, as it is not suitable for early vegetables, and is too steep for grain.

In 1887 the Director of the Experiment Station had several hundred trees planted near the top of a knoll at an elevation of 800 feet. The slope here is west and northwest and is fully exposed to the winds. It

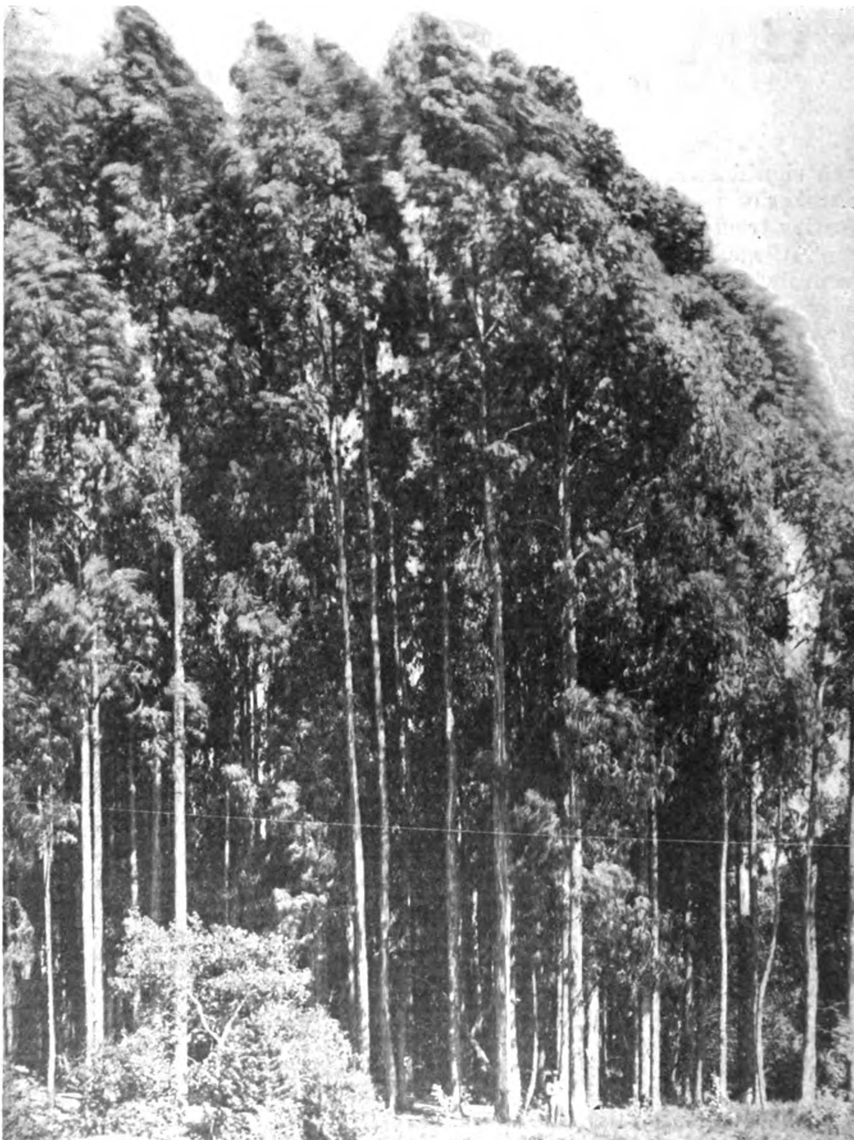


PLATE 17. EUCALYPTUS GROVE (*E. globulus*), NEAR ECONOMIC GARDEN.

was therefore, as a site, hardly equal to the average. The trees planted were English oaks, cork oaks, Monterey pines, and Monterey cypresses.

In 1888 some *Acacia decurrens* were added to the plantation, and a few miscellaneous trees, most of which died. In 1892 a row of *Eucalyptus corynocalyx*, or sugar gum, and in 1892 some *Eucalyptus globulus* were planted here. The latter were set at a considerably higher point, or at nearly 900 feet elevation. All these trees have been subject to pasture conditions, have received no care nor cultivation, and hence can not be said to give an exaggerated idea of the growth that might be expected on such Coast Range slopes as these.

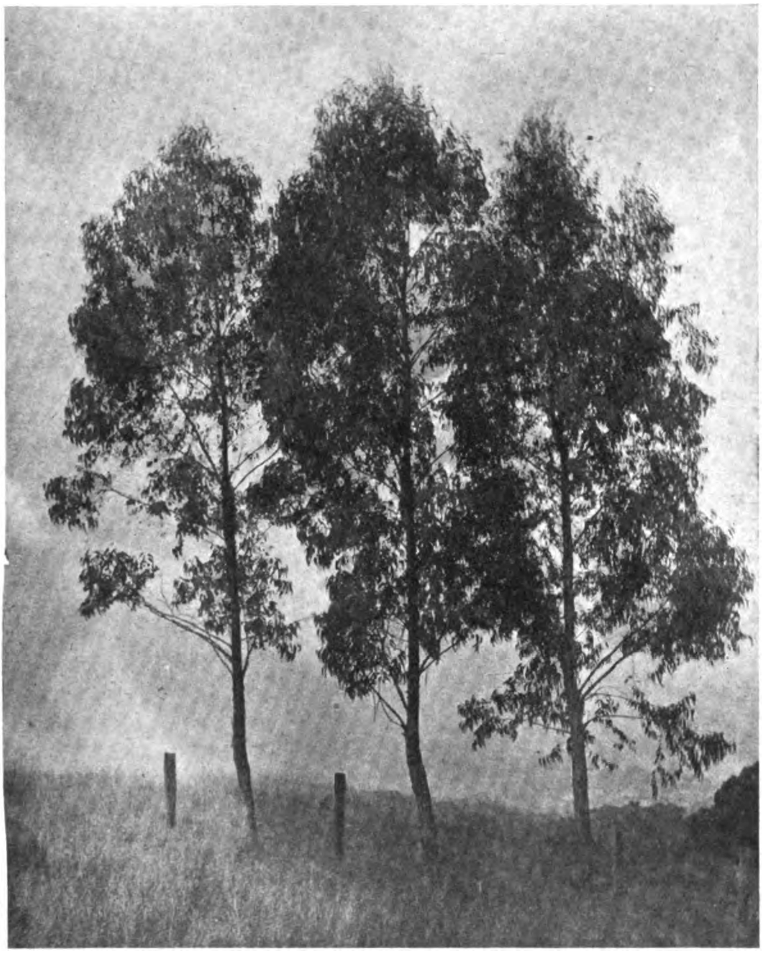


PLATE 18. E. GLOBULUS IN ADOBE SOIL OF HILLTOP.

The growth of the common blue gum, *Eucalyptus globulus*, now ten years planted, is greater than that of any other trees tested. Four trees standing near the crest of the hill, at an elevation of nearly 900 feet above the sea (or 785 feet above the Oxford street entrance to the University grounds), now show an average girth of 28 inches. The largest girths 33 inches. They are from 40 to 45 feet high and were planted 8 feet apart. They are now growing very fast. (Plate 18 shows three of these trees.)

The sugar gums (*Eucalyptus corynocalyx*), which are two years older than the blue gums, are planted on the eastern side of the main grove, which consists largely of oaks. These trees, now twelve years old, range in girth from 20 to 30 inches, and are 20 to 25 feet high. The trunks are short, not exceeding 5 feet, and many branch near the ground. The tops spread widely; cattle have eaten the leaves and smaller limbs within reach.

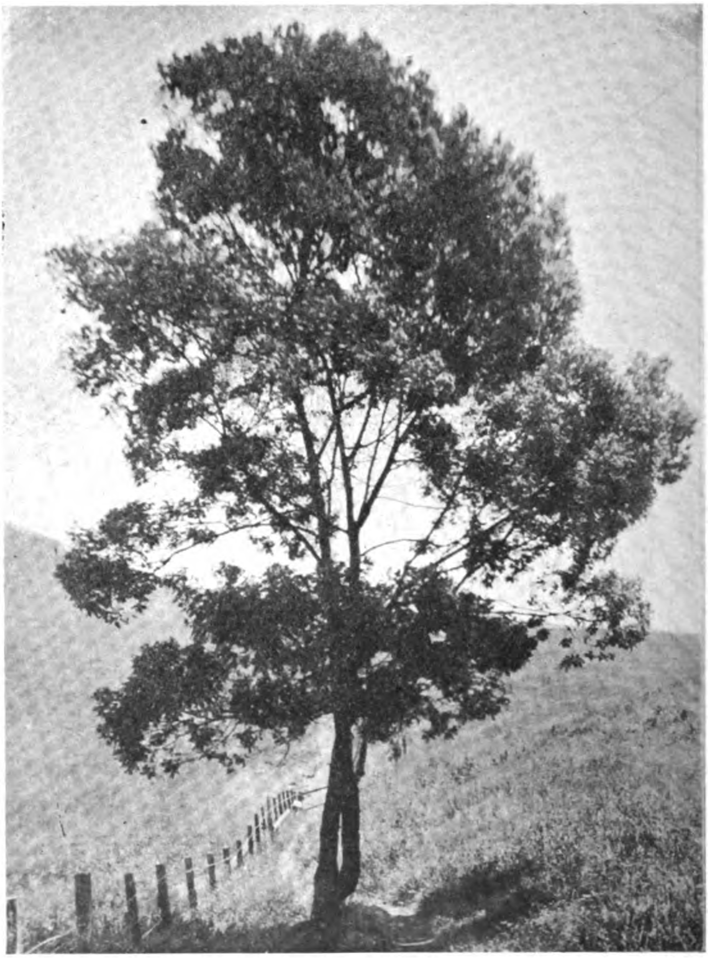


PLATE 19. ACACIA DECURRENS. ON HILLTOP.

Acacias.—The plantings of acacia originally made included *melanoxylon* and *decurrens*. The former have died; the latter are so large and healthy as amply to justify large plantations on such soils.

One of two *Acacia decurrens* near the north line, close to the fence and isolated from the main grove, is shown in Plate 19. This tree stands on a northern slope, on heavy adobe soil, with native vegetation of clover, wild oats, foxtail, etc. It girths 42 inches near the ground. The main stems girth 27 and 30 inches. The height of the tree is 30 feet. Cattle have destroyed all the lower branches. Trees of *Acacia decurrens* in the main grove, surrounded by eucalypti and oaks, girth from 38 to 40 inches (single stems).

The amount of firewood per acre furnished under these conditions by *Acacia decurrens* is greater than that from *E. corynocalyx*, but is less than that from *E. globulus*. In fuel value the acacia wood is estimated to rank higher than that of either eucalyptus. But the chief value of *Acacia decurrens*, its yield of tan bark, deserves especial consideration. Planted in a grove on such land as this, the yield of bark in, say, eight years, would be considerable. It should be fully twice as much per

PLATE 20. ENGLISH OAKS ON HILLTOP.

acre as from the lighter and more arid Santa Monica grove (see report for 1897–8, pp. 227–230). Wattle barks, as therein reported by an expert tanner after practical tests, are "as good value at $28 a ton as oak bark at $18 a ton."

Acacia pycnantha has not been tested on this hill-top. *A. mollissima*, as well as *A. decurrens* and some of the ornamental species, were planted in the southeastern portion of the tract, on a slope near Strawberry Creek, at an elevation of about 427 feet. Here the growth of the wattle acacias was very rapid, girths of from 4 to 5 feet being reached in fifteen years from planting. In this location the acacias showed considerable power of reproduction from sprouts when trees were cut and from self-sown seeds.

Oaks.—The oaks, planted in 1887 on the hilltop, elevation 800 feet, consisted of about one hundred and twenty English (*Quercus pedunculata*) and twenty cork oaks (*Q. suber*). At the present time, ninety-eight

English oaks and fifteen cork oaks remain. Many of these are branched, shrubby, and spreading, and have suffered from being browsed upon; but forty-nine of the English oaks are of good size, with trunks girthing over 15 inches, and twenty of these exceed 18 inches. The average

PLATE 21. GROVE OF OAKS, EUCALYPTS, ETC., ON HILLTOP.

height of the English oaks, however, is only 10 or 12 feet. Eight or nine trees are much taller than this, and are conquering the unfortunate tendency toward a shrubby growth. (See central oak in Plate 20.)

The best cork oaks are rather larger in girth of trunks than are the

English oaks; three are 16, 20, and 23 inches, respectively, above the ground. Of the fifteen trees, six will average fully 10 feet in height, while the others are more or less scrubby. Both cork and English oaks are very healthy, and seem as well established here as any native tree in the adjacent gulches. The oaks are on a dry western slope, where the pasturage was turning brown May 24th.

The only profit possible from oak plantations in such soil as this must come from trees constantly side-pruned and cultivated for several years. If a shrubby growth can be avoided, both the English and the cork oaks will thrive here. A plantation of twenty or more acres of cork oaks would give the matter a thorough practical test.

Other Trees.—Pines of several species planted here made good growth, reaching in some cases a girth of 15 inches, but were broken down by cattle. Monterey cypresses, though still alive, are now mere clumps with dozens of scattered stems. Cork-bark elms failed. Two California poplars (*Populus Fremonti*) are growing well, but have no economic value as compared with the eucalypts, acacias, and oaks.

Conclusions.—The poorest part of the grove is at the extreme west, exposed to the full sweep of the wind. Gophers and cattle, not drought or native vegetation, destroyed most of the trees which died. Fenced from cattle and given some cultivation the first few years, the growth would have been much greater than it is. In a larger plantation, too, the mutual shelter afforded by the young trees would be considerable.

But in spite of all drawbacks, *Acacia decurrens*, eucalypts, and oaks are well established here. Land as steep as this is rented at from fifty cents to a dollar an acre per annum, and is only used for pasturage. There are thousands of acres of such land in the Coast Range within fifty miles of San Francisco that will pay interest on a much higher valuation, if used for growing firewood, not to say a better quality of timber. As the general illustration (Plate 21) shows, the grove of oaks, eucalypts, and acacias, though small, covers the ground well, is healthy, and gives good evidence of the value of these hilltops for tree growth. On even steeper slopes and on the very crest of the Coast Range, numerous groves of blue gums exist which are now yielding profitable returns. Larger forests should therefore be planted, and other species of eucalyptus, also the wattle acacias, as well as oaks, should be given consideration.

NOTE ON THE COMPOSITION OF THE ADOBE SOIL OF THE HILLTOP.

By E. W. HILGARD.

The soil of the hilltop where the grove is situated is a very hard and black adobe clay, cracking open when dry, breaking up in lumps, and very difficult to remove, even with a pick. Samples were taken to a depth of three feet in a representative part of the grove, and those of the first and third feet subjected to a mechanical and chemical analysis by Prof. Loughridge and Mr. Triebel in the station laboratory, with the results given below.

There was in each sample from 12 to 15 per cent of coarse grits and rock fragments, which was sifted out and the analysis made of the fine earth having a diameter of one half millimeter and less.

Nos. 2430, 2432. MECHANICAL COMPOSITION OF HILLTOP ADOBE: BERKELEY.

Hydraulic Value. Velocity per Second.	Diameter of Grains.	Physical Characteristics.	First Foot. No. 2430.	Third Foot. No. 2432.
			Per cent.	*Per cent.*
Ab've 64 mm.	Above ½ mm.	Grits	12–15	12–15
64 "	.50 –.30 "	Very coarse sand	4.21	.18
64–32 "	.30 –.16 "	Coarse sand	7.21	.28
32–16 "	.16 –.12 "	Medium sand	3.89	2.11
16– 8 "	.12 –.072 "	Fine sand	5.48	3.18
8– 4 "	.072 –.047 "	Coarsest silt	5.16	2.83
4– 2 "	.047 –.036 "	Coarse silt	4.13	2.75
2– 1 "	.036 –.025 "	Medium silt	4.30	2.82
1– 0.5 "	.025 –.016 "	Fine silt	1.80	4.10
0.5– 0.25 "	.016 –.0023 "	Finest silt	42.62	51.02
0.25– ? "	.0023– ? "	Colloid clay	20.18	30.45
			98.98	99.72

The soil mass is of rather extreme physical composition, in the great predominance of very fine materials, amounting in the subsoil to over 80 per cent; and such land must always be difficult to handle in cultivation, and be uncertain on account of its dependence upon favorable rainfall. Unless very deeply cultivated it will crack open in summer, tearing the roots and drying the soil into a mass of rocky hardness. As it is not intrinsically very rich, it would be desirable to utilize it for suitable timber growth, provided sufficient root-penetration can be secured. The lack of this is probably one cause of the low growth of the English oak.

CHEMICAL ANALYSIS OF ADOBE SOIL OF BERKELEY HILLS, No. 2430.

		Per cent.
Insoluble matter	72.19	78.70
Soluble silica	6.51	
Potash (K_2O)		.33
Soda (Na_2O)		.29
Lime (CaO)		.76
Magnesia (MgO)		.76
Br. ox. of manganese (Mn_3O_4)		.08
Peroxid of iron (Fe_2O_3)		6.02
Alumina (Al_2O_3)		4.58
Phosphoric acid (P_2O_5)		.07
Sulfuric acid (SO_3)		.02
Water and organic matter		8.93
Total		99.72
Humus		1.85
Nitrogen, per cent in humus		8.70
Nitrogen, per cent in soil		.16
Hygroscopic moisture (absorbed at 15° C)		9.09

In its chemical composition this soil, as might be expected, does not differ widely from that of the lower slopes and the yellow ridge soil of the University grounds (No. 4, in Report of 1884). It is poor in potash for a California soil; and for so heavy a material the lime content, although relatively high from a general point of view, is too low to insure ready tillage. The content of phosphoric acid is an average one, its humus content is good for the arid region, and the nitrogen percentage of the humus sufficiently high. The fact that in years of abundant rainfall this land bears a very heavy growth of grasses and certain classes of weeds, shows that if improved in texture it might be highly productive for a time.

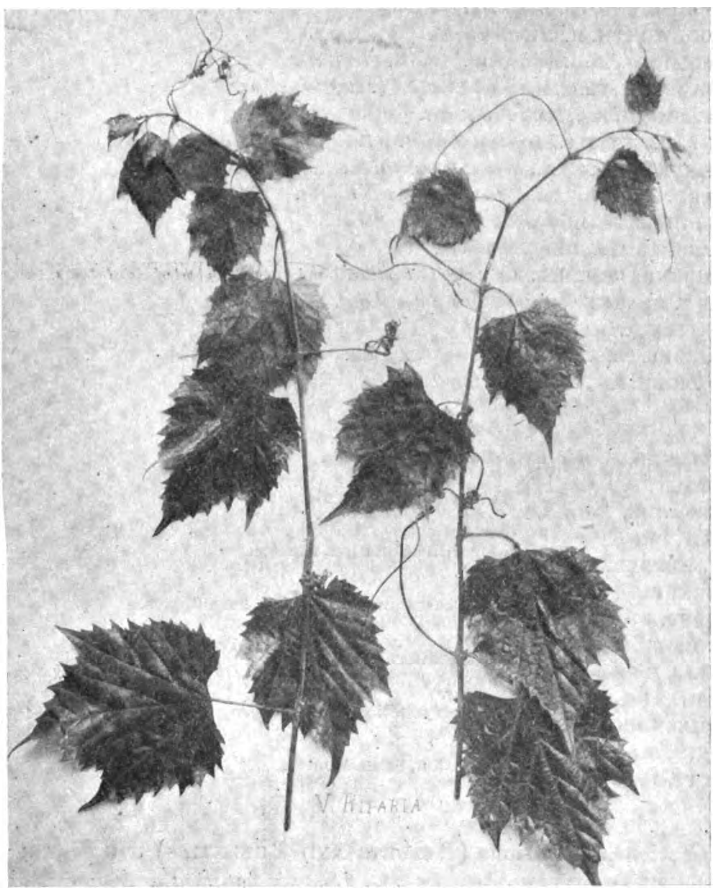
UNIVERSITY OF CALIFORNIA PUBLICATIONS.

COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

RESISTANT VINES AND THEIR HYBRIDS

BY E. H. TWIGHT.



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BENJAMIN IDE WHEELER, Ph.D., LL.D., *President of the University.*

EXPERIMENT STATION STAFF.

E. W. HILGARD, Ph.D., LL.D., *Director and Chemist.*
E. J. WICKSON, M.A., *Horticulturist, and Superintendent of Central Station Grounds.*
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A. V. STUBENRAUCH, M.S., *Assistant Horticulturist and Superintendent of Substations.*
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RESISTANT VINES AND THEIR HYBRIDS.

GENERALITIES REGARDING RESISTANT VINES.

(Abstract from Bulletin No. 131, by F. T. Bioletti.)

The most satisfactory method of combating phylloxera is the use of resistant vines, because it is applicable to all conditions and is the most economical in the end. A resistant vine is one which is capable of keeping alive and growing even when phylloxera are living upon its roots. Its resistance depends on two facts: *first*, that the insects do not increase so rapidly on its roots; and *second*, that the swellings of diseased tissue caused by the punctures of the insects do not extend deeper than the bark of the rootlets and are sloughed off every year, leaving the roots as healthy as before. The wild vines of the Mississippi States have evolved in company with the phylloxera, and it is naturally among these that we find the most resistant forms. No vine is thoroughly resistant in the sense that phylloxera will not attack it at all; but on the most resistant the damage is so slight as to be imperceptible. The European vine (*Vitis vinifera*, L.) is the most susceptible of all, and all the grapes cultivated in California, with a few unimportant exceptions, belong to this species. Between these two extremes we find all degrees of resistance, which is expressed by a series of numbers ranging from 20, indicating the highest possible resistance, to 0, indicating the utmost susceptibility. The following table shows the resistance (according to Viala and Ravaz and other authorities) of some of the best known species and varieties:

COMPARATIVE RESISTANCE TO PHYLLOXERA.

Species (Wild Vines).		*Cultivated Varieties and Hybrids.*	
Vitis rotundifolia	19	Gloire de Montpellier (Riparia)	18
Vitis vulpina (Riparia)	18	Riparia × Rupestris 3309	18
Vitis rupestris	18	Rupestris Martin	18
Vitis Berlandieri	17	Rupestris St. George	16
Vitis æstivalis	16	Riparia × Solonis 1616	16
Vitis labrusca	5	Solonis	14
Vitis Californica	4	Lenoir	12
Vitis vinifera	0	Isabella	5

The degree of resistance necessary for the production of good crops varies with the character of the soil. The resistance expressed by the numbers 16 to 20 is sufficient for all soils. A resistance of 14 or 15 is sufficient in sandy and moist, rich soils, where the vine can readily replace the rootlets as fast as they are destroyed. Fairly successful vineyards have been established exceptionally with vines having a resistance of less than 14, but as the vines become old the lack of resistance is generally shown by a weakening of the vine and a falling off of the crop. Many vineyards in the south of France grafted on Lenoir which formerly bore well, have now to be doctored with injections of bisulfid. For this reason it is advisable to reject all vines with a resistance of 13 or under, especially as vines with greater resistance can now be obtained for practically all conditions.

Resistant vines are of two kinds: (*a*) those which are grown for the grapes they produce, and (*b*) those which are useful only as stocks on which to graft the non-resistant varieties. The former are called "*direct producers*," the latter, "*resistant stocks*."

(a) *Direct Producers.*—When the phylloxera commenced to destroy the vineyards of Europe, the natural attempt was made to replace them with the varieties of vines which had proved successful in the United States, where the insect was endemic. These varieties, however, all proved unsatisfactory. Some, like the Concord and the Catawba, were insufficiently resistant, and although they could be grown where the severe cold of winter impeded the prolificness of the phylloxera, they quickly succumbed in the milder grape-growing sections of Europe.* Most of them were poor bearers compared with the prolific European vines, and finally the character of their fruit differed so widely from what Europeans were accustomed to that there was little sale for the fruit, and the wine could compete with only the very poorest quality of Vinifera wines, and brought a very inferior price. A few of the varieties introduced during that first period are still grown to a limited extent in France, chiefly the Othello and the Lenoir. They are being gradually abandoned, however, as their crops are unsatisfactory, and in many localities can be maintained only by the aid of injections of bisulfid. For some years the search for a suitable direct producer was almost abandoned by practical men, the use of resistant stocks having been so fully successful. Lately, however, renewed efforts have been made and several new direct producers are being advocated and planted to some extent. The merit of these new varieties, however, is chiefly their resistance to Peronospora and Black Rot. Phylloxera-resistance is considered of much less importance by their most ardent advocates, and indeed the advice is given to graft some of the best of these direct producers upon phylloxera-resistant stock. The main importance of these facts to California grape-growers is that they hold out hopes of permanent prosperity for the wine-making industry here, where, owing to the dryness of the climate, there is no likelihood of trouble from these serious fungous diseases of the grape, which threaten to make the growing of Vinifera varieties impossible in many parts of Europe.

*In California, these and other Labrusca varieties and hybrids resist very little longer than Vinifera vines.

(b) *Resistant Stocks.*—Though high resistance to phylloxera is essential in a grafting stock, there are other characteristics equally necessary. The Rotundifolia (Scuppernong), which has the highest resistance of any vine, is useless as a stock on account of the impossibility of grafting it with any Vinifera variety. This is due to a lack of *affinity*, which means a lack of similarity in structure and composition between the tissues of the stock and those of the scion. This lack, in extreme cases, results in an imperfect and temporary union, but when not excessive, only in a slight decrease of vigor. The affinity is not perfect between Vinifera varieties and any resistant stock, but in the case of Riparia and Rupestris is generally sufficient to insure permanence to the union, and the slight decrease of vigor consequent often results in an increase of fruitfulness. It is for this reason that certain varieties when grafted on resistant stocks, especially on Riparia, often bear larger crops than when grown on their own roots. Not all varieties of Vinifera have the same affinity for the same stock. For this reason it is desirable to be cautious about making new or untried grafting combinations on a large scale. Some varieties, such as Carignan, Petite Sirah, Clairette, and Cabernet Sauvignon, do excellently on all stocks; while others, such as Mondeuse and Gamay, do not make a very good union with any of the thoroughly resistant stocks. The Petit Bouschet and Cinsaut make very poor unions with any variety of Riparia, but do fairly well on Rupestris St. George. The Pinot Noir makes a vigorous growth upon Rupestris St. George, but bears much more prolifically upon Riparia Gloire.

Selection.—A very serious defect of many resistant stocks is a slender habit of growth. This is true of most of the vines found growing wild, and cuttings from such vines make poor grafting stock for the stout Vinifera varieties, which will produce a trunk four inches in diameter while the stock is growing only two inches. This is particularly true of the wild Riparias. For this reason great care has been exercised in selecting the stronger-growing forms, and at present we have selected Riparia varieties which almost equal Vinifera in the stoutness of their trunks. The best of these are the Riparia Gloire de Montpellier and the Riparia Grande Glâbre, the first of which has given the best results in California.

RESISTANT VINES AND THEIR HYBRIDS.

BY E. H. TWIGHT.

If we study the conditions affecting the adaptation of resistant vines, we see that the amount of lime contained in the soil, the degree of compactness, the moisture, and the fertility of the land are the most important factors. The proportion of lime in the soil has been, in many countries and particularly in France, the greatest drawback in re-establishing vineyards on resistant stock. Happily, in California we do not have to contend with that part of the problem, as few soils contain enough lime to affect even the Riparias and Rupestris, that are among the first to suffer from excess of carbonate of lime.

The compactness of the soil, generally due to the large proportion of clay it contains, is an obstacle to the good growth of many varieties of resistant stock; the roots do not penetrate easily, the ground is cold and often wet, and under such conditions the Rupestris and Riparia, for instance, do poorly. On the contrary, the Lenoir, Champini, Riparia × Rupestris No. 3306 and 101[14] will do well in such locations, and the hybrids of Solonis × Cordifolia × Rupestris will do still better. The last-mentioned have a higher resistance to phylloxera than Lenoir and Champini. If we examine the probable cause for the special adaptation to heavy soils, we see that whereas the Riparia and Rupestris have light, thin, hard roots very much ramified; on the contrary the varieties adapted to such soils have strong, fleshy roots, less ramified, with a heavier hair system on the rootlets.

When in excess, the moisture in the soil affects the vine by checking the growth of the root system. Plants growing in a very moist place may have a vigorous aërial growth, but the root system is generally weak; such a plant will suffer greatly if for some reason the supply of moisture should fall below the average. The root system in a dry exposure will always be much more vigorous, as the plant has to send its roots lower down to find the water it needs. On the other hand, a moist soil will help a vine in its fight against phylloxera, and under such conditions some stocks, though inferior in absolute resistance, may do fairly well. As a general rule, the Solonis and its hybrids are very good in wet soils.

The fertility of the soil is a condition of adaptation that we must not overlook: A Riparia or a Solonis will turn yellow and look sick in a soil where a Rupestris would do fairly well. This does not mean that a Rupestris will not do better in a good soil than in a poor one, but simply that it is more rustic in its adaptation.

VARIETIES OF RESISTANT STOCK.

We give below the adaptation of the principal varieties of resistant vines used as grafting stock or as parents in the making of hybrids. (Riparia, Rupestris, Candicans, Cordifolia, Monticola, Arizonica, Californica, Berlandieri.)

Vitis riparia.—The *V. riparia* (see title-page) is very resistant to phylloxera (18).* The grafts made on this stock are fructiferous, vigorous, and advanced in maturity. All varieties root readily from

*Resistance to the phylloxera is indicated by figures on the scale of 20 points.

cuttings and from grafted cuttings; they also take easily from field grafts. This stock has often been over-boomed, and planted in many localities where it could never grow; and from these failures some people have jumped to the conclusion that the stock is of no value. But when we consider that in France alone, seventy-two per cent of the vineyards that have been replanted are on Riparia roots, we readily see that the failures must be due to the ignorance of the conditions of adaptation. Riparias do not grow well in dry locations; they must have a good loamy soil, the best being clayey-siliceous alluvions; a deep, cool, fertile

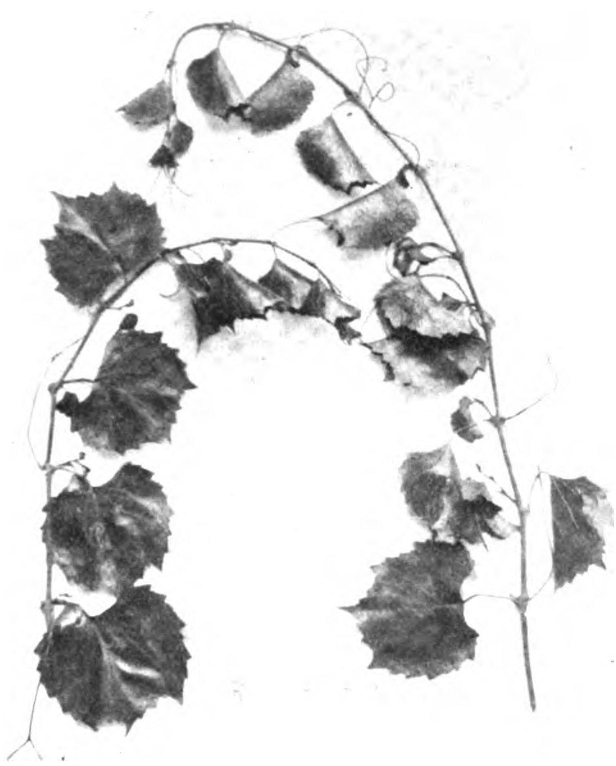

PLATE 1. VITIS RUPESTRIS ST. GEORGE.
Showing ou the right the natural fold of the leaves along the mid rib, and on the left the bracket-shaped petiolar sinus.

soil, not too wet. The two varieties mostly used are the Riparia Gloire de Montpellier and the Riparia Grande Glâbre.

Vitis rupestris.—This vine, shown in Plate 1, is found in its wild state in open places along hillsides and ravines in the arid eastern part of the region, growing in gravels and in decomposed rocks. From this natural habitat we may see that it will be well adapted to light gravelly soils, hillsides, and sandy soils. It is very resistant to phylloxera (16–18). The Rupestris vines have a larger trunk than the Riparias and show, after grafting, less difference between the scion and stock. The cuttings root easily, but not quite as well as those of Riparias; the rooting can be aided by scratching the bark of the lower part of the cutting on a short-tooth iron comb. The returns in bench-grafting are about the same as those obtained with Riparia. As the Rupestris cuttings sucker very much, it is of great importance to suppress carefully the eyes on

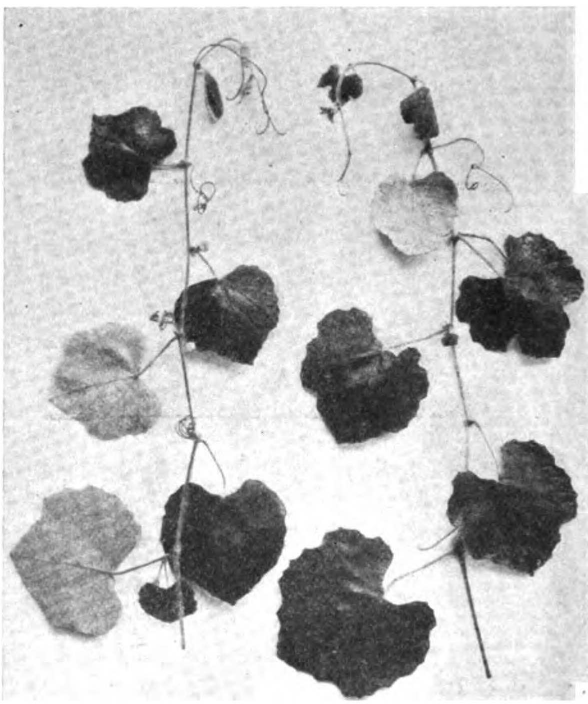

PLATE 2. VITIS CANDICANS. MUSTANG GRAPE.
Showing the entire or lobed leaves with the limb convex on the upper face. Three of the leaves are turned over, showing the very thick, white felt on the under face of the leaves.

the stock when bench-grafting. Of the two varieties that are mostly used, the Rupestris Martin is possibly a little better adapted to dry locations. The Rupestris St. George, though well adapted to gravelly hillsides and light soils, has proved also, in the last few years, to be a vigorous grower, even in lands where the water-table is close to the surface several months in the year. (Letter from Prof. L. Ravaz.)

Vitis candicans.—The *V. candicans*, or Mustang grape (Plate 2), found in its wild state in Texas and Arkansas, grows generally on bottom lands and along rivers, but it is also found in very dry locations; in these, however, its growth is not as vigorous. It does best in alluvial soils, but its large roots enable it to grow well in heavy clays. This variety is hard to grow from cuttings, but is very valuable in hybridization.

Vitis cordifolia.—This vine is adapted to the same class of soils as the *V. riparia;* it is very highly resistant to phylloxera, and does fairly well in heavy soils; it has been also used to great advantage in creating hybrids.

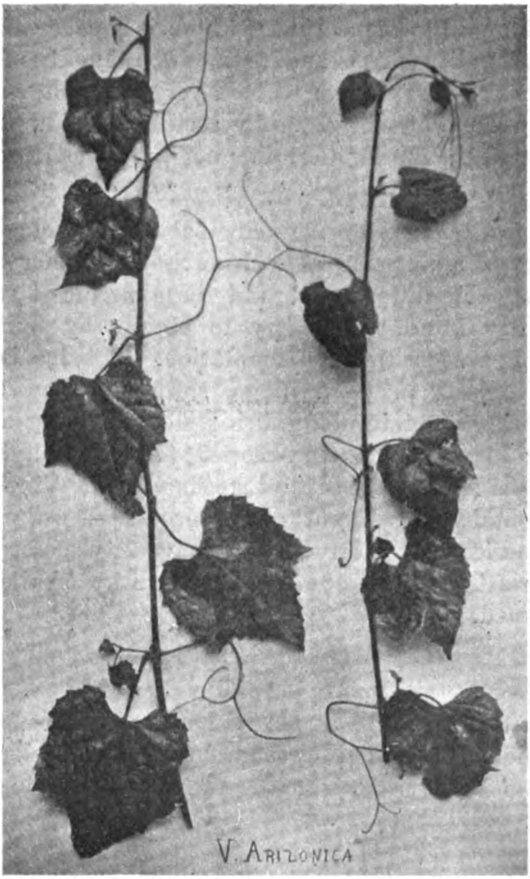

PLATE 3. V. ARIZONICA.

Vitis arizonica.—This vine (Plate 3) is found mostly in Arizona and New Mexico, while numerous hybrids of Arizonica × Californica exist in the region where both varieties grow wild. It grows well from cuttings, is nearly as resistant as Rupestris, and ought to be studied carefully. In adaptation it would hold a place between the Riparia and the Rupestris.

Vitis monticola.—This vine has only a limited range of distribution in Texas, where it is found on lands similar to those where the Rupestris grows, but containing generally a high percentage of lime. It comes next to the Berlandieri as a resistant to chlorose, which is caused by excess of lime in the soil. This stock is a very good element in hybridizing, and may turn out to be very valuable as a direct grafting stock.

Vitis californica.—The wild native vine of California; it has a resistance to phylloxera too low to be of much use.

Vitis Berlandieri.—This vine is found in Texas, New Mexico, and Mexico, growing on limestone ridges, where it resists excessive drought and heat. The quality of resistance to lime would not be of much interest in California, but it may prove to be a very valuable stock in heavy, dry soils, as probably its large fleshy roots will allow it to penetrate readily. Though the Berlandieri does not grow well from cuttings, its hybrids have not that drawback.

From these few remarks on the principal resistant stocks we may see that the range of adaptation of each variety is rather narrow. This observation led the nurserymen and the experiment stations in the countries mostly interested, to try to obtain, by hybridizing, new varieties having a wider range of adaptation. This has been done with two different objects in view. Some simply crossed the American resistant varieties to obtain new grafting stocks having a larger range of adaptation; we will call these Americo × American hybrids. Others tried to cross the American resistant stocks with the Vinifera-producing varieties, to obtain a resistant direct producer; we will call these Vinifera × Americans. So far the latter have only succeeded in making some good grafting stocks, the bearing qualities of the Vinifera not being transmitted.

AMERICO × AMERICAN HYBRIDS.

Mr. Munson, in the United States, and a great number of scientists in Europe (Couderc, Millardet, Grasset, Foex, Ravaz) have created a large number of new hybrids, some of the most promising of which we will review.

Riparia × Rupestris.—This group is probably one of the most interesting. Among the varieties selected as the best at present we find Nos. 3306 and 3309 of Couderc and No. 101^{14} of Millardet. They are very resistant to phylloxera, root easily from cuttings, and give a high percentage of good grafts. The trunk increases rapidly in size, so that there is little difference between stock and scion; the fructification after grafting is good and regular. The range of adaptation is a combination of that of Riparia and of Rupestris; Nos. 3306 and 101^{14} being also able to do well in soils a good deal more compact in nature than those suitable for either of the parents; No. 3309 stands drought well.

Solonis × *Riparia*.—These hybrids are well known for the heavy-bearing character they communicate to their grafts. The affinity is very good and they are particularly well adapted to wet lands. While adapted to the same soil-conditions mentioned above for the Solonis, they have a much higher resistance to phylloxera than the latter. The best known are Nos. 1615 and 1616 (Couderc).

Solonis × *Cordifolia* × *Rupestris*.—These have great vigor, which they hold from the Cordifolia × Rupestris, while they take some of the characters of the Solonis in moist locations. They have proved very valuable in heavy moist clays. No. 202^4 of Millardet and Grasset is among the best.

Riparia × *Cordifolia* × *Rupestris* (No. 106^8).—Is very similar to the last group regarding its vigor, but is adapted more particularly to very arid locations, where it has proved superior even to the Rupestris Martin. It will probably be of great value in some of our adobe lands.

Berlandieri × *Riparias*.—These hybrids have been studied in France, mainly to create a stock having the resistance of the Berlandieri to chlorose, and the easy rooting of the Riparias. Some of the selections have given very satisfactory results (157, 420, 34E). The Berlandieri hybrids are very productive after they have been grafted. The roots are very strong and both surface and deep roots are abundant; as we said before, this hybrid may prove to be very valuable in stiff, dry soils.

VINIFERA × AMERICAN HYBRIDS.

Lenoir.—Though the question of the origin of the Lenoir is not very well settled, it probably comes in this group of Vinifera × American. The Lenoir has a great affinity for the Viniferas, so that when grafted in the field it gives very good results. It does not root as well from cuttings and does not bench-graft as well as the Riparias and Rupestris, but still gives satisfactory results. The resistance to phylloxera is not high (12–13), which is too low unless it is planted in a soil perfectly adapted to its growth. In rich soils, fertile, and with plenty of moisture, it does very well, but these are also good Riparia soils. When the soil becomes compact, then the Lenoir would do better than the Riparia. But for these heavy lands we have to-day such varieties as the Solonis × Cordifolia × Rupestris, the Riparia × Cordifolia × Rupestris, the Riparia × Rupestris 101^{14}, which are far superior to the Lenoir in resistance, and ought therefore to receive the preference.

Mourvedre × *Rupestris* or *Mataro* × *Rupestris* is a very fine selection of Vinifera × American; the 1202 grows well in all soils from a chalky land to a deep alluvial one. It has been found quite resistant to phylloxera, and particularly well adapted to heavy clay soils.

Bourrisquou × *Rupestris* and *Carignane* × *Rupestris* have also a large range of adaptation, but are specially adapted to dry locations.

Aramon × *Rupestris* (*1 and 2*) are found to do splendidly in clay soils of medium fertility and in soils underlaid with clay. We have a great many of these soils in California, and this stock may prove to be of great value. The roots are superficial, like those of the Riparias, but they are large and fleshy.

MUNSON HYBRIDS.

Mr. Munson has created, in recent years, a great many hybrids of Americo × Americans and of Vinifera × Americans; some of these are quite promising, but the local results that have been published at different times can not be taken as final proof of their value. We have not yet sufficient data to give personal observations on these, but will give the opinion of Professors Viala and Ravaz, the French viticultural authorities, on some of the Munson resistant stocks.

Vitis champini (Candicans × Rupestris).—Can be divided in two groups: the glabrous and the tomentose. The glabrous group has a resistance of 14, the tomentose of 12. They are harder to grow from cuttings than the Rupestris, but have the advantage of being good growers in heavy clays and of having large wood. Their low resistance is, however, a grave objection, especially when we have some varieties that do just as well in the same locations and which are much more resistant.

Candicans × *Monticola* (Gwyn, Sanford, Belton).—The latter is probably the best; it has a resistance of 16, is very vigorous, has a large trunk, does well in compact soils, and has large wood, but does not grow well from cuttings.

Novo-Mexicana.—This is probably a Candicans × Riparia × Rupestris. The Solonis, Moobetie, Hutchison, and Doaniana are some of the varieties of this group. They are adapted to Solonis soils; that is, rich, with plenty of moisture. They do well in lands that are rather wet and salty (alkali). They grow well from cuttings and have good-sized wood. The resistance to phylloxera is not first class, but is sufficient in soils well adapted to them. In lands not well adapted, they succumb rapidly to the attacks of the insect. The Hutchison is more vigorous and resistant; the Solonis and Doaniana less so.

RESPECTIVE VALUE OF AMERICO × AMERICANS AND VINIFERA × AMERICANS.

We have seen that in both of these groups of hybrids we may find some varieties that are well adapted to our special conditions; in both, we find a good resistance to phylloxera *in the selected stock*. Which of these should we plant in our vineyards?

It may be said in a general way that the Americo × American hybrids, as well as the ordinary American grafting stocks, make the Vinifera scions that are grafted on them bear more heavily than they would if they were on their own roots. They come into full bearing earlier, and generally the fruit will ripen a few days earlier. But the variety of Vinifera grafted on these roots does not reproduce exactly the type it represents when on its own roots: the grapes may be larger, but there is a slight difference in the flavor and the per cent of sugar. The Vinifera vines grafted on Vinifera × American hybrids retain better their original qualities and have a better affinity between stock and scion.

The heavy bearing of the vines grafted on Americans or on Americo × American will exhaust the land sooner; so that fertilizing will have to be resorted to earlier, and it is a known fact that heavy fertilization affects the quality of the grapes.

From these remarks we may conclude that the American resistant stock and their hybrids will probably be favored by those who look to quantity more than to quality; while for the fancy wine grapes and the better grades of table and raisin grapes the Vinifera × American resistant stock will be chosen. The choice between the two groups is mainly an economic question.

A warning must be given regarding the selection of the stock. We find hundreds of thousands of hybrids of each kind, but only very few have been carefully selected. Because the Riparia × Rupestris 3306 or 3309 are good, it is by no means a reason for any "Riparia × Rupestris" to be equally good. The *number* of the selection is as important, and in fact more important, than the name of the stock.

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COLLEGE OF AGRICULTURE.

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THE CALIFORNIA SUGAR INDUSTRY.

PART I.

HISTORICAL AND GENERAL.

By GEORGE W. SHAW.

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BENJAMIN IDE WHEELER, Ph.D., LL.D., *President of the University.*

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ILLUSTRATIONS.

INTRODUCTION.

Generally favored by nature with economic conditions adapted to the production of a high-grade sugar beet and to the successful extraction of the sugar from it, still California has not held its position as the largest producer of beet sugar in the United States, for this year she will be outranked in the amount of sugar produced by Michigan, where the industry is but five years old, and which State has natural conditions far less adapted to the industry, and notwithstanding California has more acres well adapted to the industry than any other State in the Union and has had a third of a century of experience.

Under the running title, "The California Sugar Industry," it is proposed to review the conditions as they exist in the State to-day from both the manufacturing and the agricultural standpoint, and to discuss such experimental work bearing upon this industry as has been and may be undertaken by this Experiment Station.

This first number of the series is naturally historical in a large measure. Since California is the mother State of the industry, it is fitting that its early history should be recorded in some connected manner that it may be easily accessible. Part I also presents statistical matter of much value to manufacturers and others who may be studying the subject with reference to the establishment of factories. This is particularly true as the periods covered by the reports are the longest on record in this country and cover a great variety of soils and climate.

Part II will deal mainly with a review of the present agricultural conditions and practices, and suggestions for improving the same deduced from observations in the field and laboratory.

The writer desires to acknowledge the courtesy of the sugar companies in supplying the basal figures from which the tables have been computed.

E. H. DYER,
Father of the Beet-Sugar Industry.

P. C. SPRECKELS.

THE CALIFORNIA SUGAR INDUSTRY.

PART I. HISTORICAL AND GENERAL.

California was the first of the United States to successfully manufacture beet sugar upon a commercial scale. She has placed beet sugar upon the market for the past thirty-three years. Within her borders is located not only the pioneer beet-sugar factory of this country, but also one of the largest factories in the world, both of which are in successful operation this year. California leads in the annual production of beet sugar, yet comparatively few people outside of the immediate neighborhood of the beet-growing sections have any adequate conception of the present status of the industry.

The present localities in which beets are produced for sugar purposes extend from the San Franciscan region on the north, along the coast counties, to San Bernardino County on the south. Within this area some 60,000 acres are devoted to sugar-beet growing, the product from which, under favorable conditions, represents an annual money value exceeding $6,000,000, assuming the average price to be 4¼ cents per pound.

The relative importance of the industry, as compared with a few of the other leading products, may be seen from the following table, taking the reports of 1902 as the basis:

	Pounds.	Value. (at average price.)
Butter	31,528,000	$6,305,600
Potatoes	24 000,000	2,760,000
Citrus fruits	450,000,000	10,000,000
Raisins	96,000,000	5,280,000
Hops	10,670,000	1,493,800
Beet sugar	160,000,000	6,800,000
Beans	115,000,000	4,600,000
Wool	25,835,700	3,100,000
Wheat	18,530,000	12,452,000
Prunes	150,000,000	6,000,000

Thus it will be seen that the value of the beet sugar produced in the State practically equals the value of the butter product and of the prune crop; equals about three fifths of the value of the citrus fruits; more than doubles the value of the potato crop; surpasses the value of the raisin crop by $1,000,000, and the bean crop by $2,000,000; and equals one half the value of the wheat crop.

Factories.—Eight factories are engaged in the production of this sugar, the location, year of establishment, and the capacity of each being shown in the following table:

Established in—	Locality.	County.	Operated by—	Capacity. (Tons, 24 hrs.)
1869	Alvarado [1]	Alameda	Alameda Sugar Co.	900
1888	Watsonville [2]	Santa Cruz	Spreckels Sugar Co.	1,000
1891	Chino [3]	San Bernardino	American Beet Sugar Co.	750
1897	Los Alamitos [4]	Orange	Los Alamitos Sugar Co.	700
1898	Crockett [5]	Contra Costa	Calif. and Hawaiian Refining Co.	1,200
1898	Oxnard [6]	Ventura	American Beet Sugar Co.	2,000
1899	Spreckels [7]	Monterey	Spreckels Sugar Co.	3,000
1899	Betteravia [8]	Santa Barbara	Union Sugar Co.	500
Total capacity, tons per day				10,050

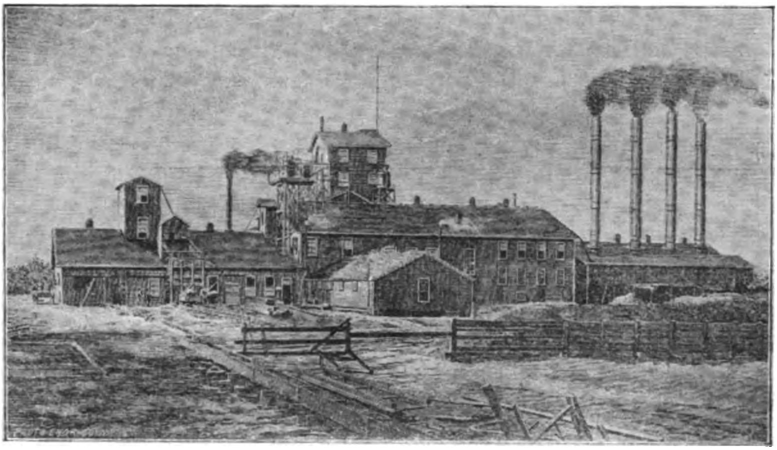
NOTE.—The small figures refer to the same numbers on the small map on the cover.

Exclusive of the land owned by these companies, the capital invested in the factories will aggregate approximately $12,000,000, to which may be added as a working capital and that invested in land, enough to raise the total amount invested by the companies themselves in the industry to about $20,000,000.

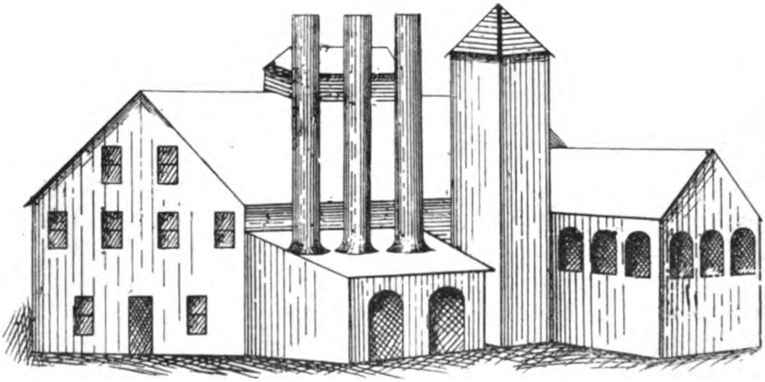
THE EARLY PERIOD OF THE INDUSTRY. (1857 TO 1880.)

The Pioneer Factory.—As early as July 20, 1857, the "California Cultivator" asks the question, "Who will pioneer the manufacture of beet sugar?" and at the same time sets forth certain advantages in California, among which may be found the "get-rich-quick" statement that "two crops can be grown annually averaging 40 to 50 tons per acre," the spirit of which the writer fears has not altogether died out, even to-day. As if to answer this query, a company was organized at San José, but no other steps were taken toward the manufacture of sugar. Although the press of the State constantly agitated the matter, yet no further active steps toward organization were taken until 1869, when Messrs. Bonesteel, Otto & Co., who at the time were engaged in a small way in the business at Fon du Lac, Wis., became associated with certain California men and organized "The California Beet Sugar Company," having a capital stock of $250,000. The stockholders of this pioneer company were C. I. Hutchinson, Flint, Bixby & Co., T. G. Phelps, E. H. Dyer, E. R. Carpentier, E. F. Dyer, W. B. Carr, W. T. Garratt, and E. G. Rollins, all of California; and A. D. Bonesteel, A. Otto, and Ewald Klinean, of Wisconsin. Immediately on the arrival of the Eastern parties, who were to assume the technical management of the business, in 1870, active operation was begun by the erection of the factory on the farm of E. F. Dyer, at Alvarado, and on November 17th, of the same year, the first beet sugar was made in California. From that time until the present, excepting only one year, it has been annually upon the market.

This pioneer factory cost approximately $125,000, had a capacity of 50 tons per day, and turned out raw sugar at a cost of 10 cents per pound when sugar was selling at 12 to 15 cents on the San Francisco



(a) Original Alvarado Sugar Factory. Capacity, 50 Tons.



(b) The Isleton Sugar Factory. Capacity, 75 Tons.

PLATE I. TWO PIONEER SUGAR HOUSES.

market. The company paid $3.50 per ton for beets delivered, and manufactured in the first campaign 500,000 pounds of sugar. Plate I (*a*) shows a picture of this early factory.

The operation of this mill is described as follows: * "The beets are washed and rasped, and the juice is extracted by a centrifugal screen. Defecation is effected by lime, and purification by carbonic acid and

* Pacific Rural Press. Vol. I, No. 1.

animal charcoal. They use vacuum pans for the juice-boiling; and again centrifugals for extracting the molasses from the crystal sugar."

A year previous to the building of the Alvarado mill, "The Sacramento Valley Sugar Company" was organized by a Mr. Wardsworth, who had previously * "put up an experimental plant, and proved the fact that our beets were good for sugar; under which assurance a 70-ton plant was ordered from Germany." But subsequently the company decided to delay one year, thus losing the honor of priority. In 1871 the factory was erected at Brighton, near Sacramento, having a nominal capacity of 75 tons per day, at a total cost of $250,000, the machinery costing $160,000. Under date of November 18, 1871, the "Rural Press," in describing the mill, says, "The new factory goes into operation this week, using the diffusion system instead of the centrifugal for removing sugar." This was the first diffusion battery operated in America.

About this time the San José project again indicated life, and we find Mr. Tyler Beach, secretary of the San José Sugar Company, saying that $40,000 of the $200,000 capital stock has been subscribed.

In this same year Salinas makes its first movement toward demonstrating the possibilities of beet-sugar production by shipping 1,200 pounds of beets to the factory at Alvarado for a working test. This appears to have been the last active effort at San José, but its more fortunate neighbor now has the proud distinction of having the largest beet-sugar factory in the world.

The Alvarado factory continued to produce sugar with varying success for four years, when internal difficulties in the company arose and the Eastern parties transferred their connection to Soquel, Santa Cruz County, and together with capitalists of San Francisco there started a third factory. The Alvarado factory struggled on until 1876, when drought destroyed the entire crop, and the factory closed its doors.

The Sacramento Valley Company ran successfully in 1871, but in 1872 the beet crop was much injured by the ravages of the "army worm." The campaign of 1873 opened on August 5th and extended to November 22d, the beets showing an average of 8 per cent sugar, and an average yield of 10 tons per acre. The company manufactured 982,120 pounds of sugar, inclusive of first, second, and third grades. This factory continued to contend with army worm, grasshoppers, drought, inexperience, and opposition on the part of interested parties until 1875, when the factory closed and the machinery was offered for sale at $45,000.

Early Efforts to Crush the Industry.—It is interesting to note that the early attempts to introduce the manufacture of sugar from beets on the Pacific Coast were met with efforts to crush the industry similar to those used in the beginning of the century, when the beet first threat-

* Pacific Rural Press, Vol. I, No. 1.

ened to compete with cane for the championship of the world's sugar production (and which with the renewed interest in the industry have again been apparent during the past year); for under date of January 1, 1871, we find the following in the "Pacific Rural Press":

"Whenever any enterprise is started in this city or vicinity there is always a hard fight made by jobbers and importers to crush out the new enterprise. Of course, the beet-sugar enterprise is no exception. The first attack was a material reduction in the price of the class of sugar manufactured at Alvarado. * * * The next attempt was to frighten capital from investing in the numerous projects for other manufactories which were set on foot as soon as the success at Alvarado was made known."

The effect of these attempts may be the better realized if it be stated that at the time the factory started at Alvarado sugar was selling on the San Francisco market at 15 to 16 cents per pound, and as the beet sugar came on the market the price was suddenly put down to 11 cents; this, together with the difficulties attendant upon inexperience and lack of proper management, proved too much for the struggling company.

The importance of the manufacture attained in California is indicated by the following figures:

	Pounds.
*1870	500,000
1871	800,000
1872	1,125,000
1873	1,500,000

The Soquel Factory.—The factory at Soquel made its first sugar in 1874. There are some conflicting data as to this factory, but Mr. W. R. Radcliffe, of the "Watsonville Pajaronian," says† that the factory ran in 1876, and the "Pacific Rural Press," under date of November 10, 1877, states that "the factory was running at full capacity and the company would cut about 9,000 tons," for which they paid $4.75 per ton. The same paper states that this factory had a run of two months in 1879.

The Isleton Factory.—In 1877 the interest again revived about Sacramento, and another factory was erected at Isleton, an island in the Sacramento River ill adapted to beet culture, on account of the high water-table, the water often rising above the level of the beet fields. It should be said, however, that the original idea of the factory was the manufacture of sugar from watermelons, but this not proving feasible, attention was turned to the beet. On account of the poor agricultural conditions, the project was abandoned by the company after the first campaign in 1878. The factory had a revival for another year in 1880, during which single campaign it was under lease by Mr. H. M. Ames,

* Report of California State Agricultural Society, 1874.

† Pacific Rural Press, Vol. XIX, No. 1.

of Oakland, a stockholder in the factory at Alvarado, which company in the meantime had been reorganized, as will appear later.

The Standard Sugar Refining Co.—Thus it appears that, excepting 1887, when the Alvarado factory did not run, beet sugar has been annually on the market in California since the inception of the industry in 1870; for in 1879, overlapping the failure of the Soquel concern, the Alvarado company was reorganized by Mr. E. H. Dyer, who, believing that with proper management the business could be successfully conducted, had purchased from the old company the buildings and a portion of the land. He found it somewhat difficult to interest capital in the face of so many failures, but finally succeeded and organized the Standard Beet Sugar Company, with a capital of $100,000. For the purpose of increasing the stock to $200,000, the company very shortly reincorporated under the modified title, "The Standard Sugar Refining Company," with the following officers: O. F. Griffin, president; J. P. Dyer, vice-president; E. H. Dyer, general superintendent; W. F. Ingalls, secretary; other members of the company being R. N. Graves and G. H. Waggoner.

The year 1880 saw three factories producing sugar in California, the output from which reached the maximum for this early period. The "San Francisco Grocer" gives the following figures for that year:

	Pounds.
Standard Refinery (Alvarado)	1,574,233
Isleton factory	298,427
Soquel factory (estimated)	300,000
Total	2,172,660

THE DORMANT PERIOD. (1880 TO 1887.)

This may be said to end the early factory period of the industry in California. From this time (1880) until 1888 the factory at Alvarado was the only one to survive and keep alive the spark of interest in the United States, which in our day has kindled into a mighty flame. There is no greater evidence of the vitality of the industry than the continued existence of this pioneer factory in the face of active opposition and exposed to direct competition with the cheap products imported from Hawaiian Islands under the then existing treaty.

The continued operation of this factory in the face of the adverse conditions named, while perhaps partially accounted for by its favorable location, is undoubtedly more directly due to intelligent and close attention to the details of its various operations in the field and factory than to any other factor.

From 1880 to 1888 may well be styled the dormant period of the industry not only in California, but also in the United States generally.

Since the time of its reorganization the factory has manufactured sugar annually. The first season's run of this new company netted a clear profit of $1,411.73, which was the first money actually made in the manufacture of beet sugar in this State, and probably in the United States. This factory continued to run on a paying basis for six consecutive years, the greatest earnings for a single year being $44,732.35.

While this company did fairly well until 1884, after that date one calamity and another befell the company, and from that time until 1886 it had but a struggling existence. For the season of 1884 the company made extra exertions to induce farmers to grow beets, resulting in a great increase in acreage. All conditions for growth being favorable in that season, a very large crop was the result—larger than the factory could easily handle. A very warm winter resulted in a lowering of the sugar content of the beets that had been delivered, and finally the factory found it unprofitable to longer continue the campaign, even while it had many tons of beets on hand. During this campaign, too, hostilities commenced between the two San Francisco refineries, which completely demoralized the sugar market; and between the two unfortunate occurrences the factory failed to make a profit from this large crop. The low price of sugar continued to hold, and although the factory continued to run without financial loss until its machinery was badly damaged by the explosion of a boiler in 1886, it was unable to make a profit. The tons of beets worked and the sugar made therefrom are shown in the subjoined table; all data, except as indicated, being furnished from the books of the company:

TABLE I.

RESULTS AT ALVARADO, 1880–1888.

Campaign.	Beets Worked, Tons.	Sugar Made, Pounds.
1879–80	13,000	1,231,966
1880–81	9,326	1,184,973
1881–82	11,230	1,415,847
1882–83	10,489	1,098,583
1883–84	7,901	1,027,826
1884–85	*16,728	1,906,000
1885–86	*10,500	†1,200,000
1886–87	12,596	*1,438,000
1887–88	No beet sugar made in United States.	

At the end of the eighth year the low price of sugar and active competition, coupled with damage from a serious boiler explosion, forced the company to improve its facilities for manufacture, and in 1887 the Pacific Coast Sugar Company was organized and a new factory erected. This company operated one year, and then sold the factory to the present Alameda Sugar Company (see page 34).

* Estimated.

† Willett & Gray's Statistical Sugar Trade Journal.

The final success of this factory was mainly due to the indomitable energy of Mr. E. H. Dyer, to whom belongs the credit of inaugurating this new industry on the Pacific Coast. He still resides in close proximity to the factory and is still a stockholder, although on account of declining years, he has retired from active business life.

During this period it is important to record that through improvements in machinery and in methods of handling the juices, developed largely through adapting them to American conditions, the Dyers had been able to reduce the cost of manufacturing sugar from 10 cents per pound in 1879 to 5 cents in 1887.

The character of beets grown during this period is fairly represented by the following figures from the records of the factory:

TABLE II.

SHOWING SOME FIELD RESULTS AT ALVARADO.

Field.	Total Solids.	Sucrose.	Other Solids.	Purity Coefficient.	Remarks.
1..	16.34	13.85	2.57	83.94	Planted 315 acres; will average 15 to 20 tons per acre.
2..	16.85	14.37	2.425	85.7	Planted 10 acres; yield, 15.3 tons per acre.
3..	16.08	13.22	2.88	82.15	Planted 10 acres; yield, 23.7 tons per acre.
4..	16.20	13.70	2.57	84.18	Planted 20 acres; yield, 18 tons per acre.
5..	16.14	13.54	2.60	83.26	Planted 12 acres; yield, 20.5 tons per acre.
6..	16.70	14.2	2.50	84.50	Planted 18 acres; yield, 23 tons per acre.
7..	15.28	12.45	2.88	81.41	Planted 10 acres; yield, 15.3 tons per acre.
8..	15.98	13.62	2.31	85.50	Planted 8 acres; yield, 19 tons per acre.
9..	16.54	13.48	3.06	81.40	Planted 10 acres; yield, 17.5 tons per acre.
10..	16.22	13.57	2.65	83.62	Planted 7 acres; yield, 15 tons per acre.
11..	15.27	11.67	3.25	78.92	Planted 5 acres; yield, 26 tons per acre.
12..	17.09	14.33	2.67	84.00	Planted 20 acres; yield, 23.7 tons per acre.

One thing noticeable in this table is that the beets produced in these earlier years were fully equal in richness to those produced in Europe for a like period. The large differences in yield indicated in the table were not due so much to variation in the fertility of the soil as to unlike and irregular methods of cultivation.

In speaking of this matter Mr. Dyer says: "The experience of six years has shown that the average yield of beets per acre has steadily increased, and this increase has been due to improved agriculture alone. At first the farmers (the company does not grow beets) were largely ignorant of the correct method of beet culture, and as this ignorance disappeared the results were seen in an increase of the crop."

During this period Dr. Hilgard, of the University of California and Director of the Experiment Station, realizing the adaptability of many sections of the State to this industry which promised so much to American agriculture, repeatedly urged its introduction into the State on a more extended scale, his advocacy often meeting with active opposition, even by parties who later became convinced of the truth of his contention and became very heavily interested financially.

That strong opposition still held toward the industry is well indicated by an article signed L. D. Wilson and published in one of the papers of that date:

*"Capital has been seduced into these ventures by plausible representation and magnificent figures. * * * Every good citizen who has a regard for the permanent prosperity of the State, whether engaged in sugar-making or not, must regret so large an expenditure of money fruitlessly. It has a dampening effect upon investment in manufacturing enterprises of more meritorious character."

But notwithstanding the attacks of the enemies of the industry, the factory at Alvarado, being favorably located and well managed, continued to do business, as will the factories of to-day when not handicapped by unfavorable economic conditions of soil, climate, and extravagant management, notwithstanding the recently ill-advised and insidious attacks of deeply interested parties.

EARLY ATTEMPTS TO DRY BEETS.

Mention should be made, before leaving this early historical period, of the interest aroused at Los Angeles in 1880 by Mr. Thomas Gennert, who had previously been connected with the enterprise in Canada and Maine. In connection with Mr. Nadeau, he hoped to grow beets and sun-dry them for preservation and transportation. Their factory, however, failed to make sugar successfully from the dried beets. The reason of the failure does not appear, but it was probably due to some imperfection of machinery or faulty manipulation, for 50 tons of the dried beets were sent to the Alvarado factory for a working test and sugar was successfully made from them; thus seeming to demonstrate the contention of Dr. E. W. Hilgard, of the University of California, who had discussed the matter in a preliminary way in the Annual Report of the Station in 1879 and again in the following year. Although attempts had been made at drying beets by artificial heat and it had been practiced to a very limited extent in Europe, yet the great expense attendant upon such drying had rendered it unprofitable, †"notwithstanding the advantage of a high purity coefficient of the extract, resulting from the fact that in that drying process a portion of the impurities of the fresh juice is rendered insoluble, and thus remain behind in the leached pulp of the fire-dried beets." These experiments are particularly interesting, inasmuch as they represent the only ones of the kind attempted in this country, and further show the character of the beets produced in this early period of the industry.

* Pacific Rural Press, Vol. XIX, No. 1.

† Report of California Experiment Station, 1879.

The first experiments in drying were conducted on a small scale in 1879 at the suggestion of Mr. Thomas Gennert. The sliced beets were dried in the open air, as fruit is dried to-day, and samples were sent to the Experiment Station for analysis.

In discussing the results in the "Pacific Rural Press," Dr. Hilgard says:

"In from three to four days, according to the conditions of the weather, the fresh beets were reduced to one fourth of their weight, and thus converted into a material containing from 56 to 63 per cent of cane sugar, which, of course, would readily bear the cost of shipment to any reasonable distance. There could be no difficulty in keeping such a material in properly prepared bins, in this climate, for years; and the extract from it was found by me to be fully up to the standard of purity observed in the fresh beet juice itself. In 1880 these experiments were repeated, unfortunately on too large a scale for an untried industry. The season was unfavorable in every respect, the sugar percentage being low and the weather at the time very cold and foggy, so as to retard the drying and render the product liable to spoiling, without special precautions for which no preparations had been made. The result was as good as could be looked for, although there was disappointment in not securing a purer product, which could have been worked with less expensive apparatus than the fresh beets. Partly in consequence of this, the process and its product were withdrawn from the supervision of the expert who had thus far managed the enterprise; and when, some months later, the bulk of the dried roots was sent to the Alvarado factory for working, it was found that the extract was excessively impure, and that only a very small product of sugar could be obtained, the cane sugar percentage having fallen to about half of the original one. Examination showed that the beet chips had undergone a partial fermentation, evidently from an exposure to dampness that could and should, as a matter of course, have been avoided by proper storage. This was the extent of the failure which, at that time, was claimed by some as disposing finally of the project of sun-drying beets in California. So far from this, it has merely shown that the rough, wholesale method of procedure for which Californian agriculturists seem to entertain a special predilection as the only 'practical' mode of doing things, can not be applied to this industry; and that, like wine-making, it requires some technical experience and reasonable care to be successful in this preliminary step of the manufacture, as in the succeeding ones. But that with some experience, and with proper appliances, this mode of conserving the raw material for the beet-sugar factories throughout the year can be made successful and profitable in California I see no reason to doubt. If so, it will constitute a special advantage for the industry that can probably be realized in few other countries."

While the matter of drying beets would appear perfectly feasible, as indicated, yet the writer believes as a practical application it will hardly appeal to manufacturers until they secure a much larger supply than is now the case at any factory in the country. Outlying cutting-stations, combined with pipe-lines for conveying the juice to a central plant, as about Lehi, Utah, is a far more feasible industrial venture.

That the beets grown in this southern area in this early period were of good quality for sugar purposes is indicated not only by the results stated above, but also by a series of seven analyses reported by Mr. Gennert, averaging 14.7 per cent sugar and 88 per cent purity, and giving an average yield of 15.6 tons per acre.

THE MODERN PERIOD. (1888 TO 1902.)

The industry took on new life in 1888, in which year, to meet the lessened price of sugar and the competition offered by the erection of a new factory at Watsonville equipped with more modern appliances, the Alvarado factory improved its machinery, and later, in 1897, increased its capacity to 900 tons per day.

It was not, however, until the McKinley tariff, which went into effect in October, 1890, giving a bounty of 2 cents per pound on all sugar produced in the United States, that the industry could be said to be sure of a footing. Whatever may be thought of the wisdom of this step, it is certain that it gave new hope to both operators and growers, and between the time that this Act went into effect in October, 1890, and the following June, some $6,000,000 had been invested in beet-sugar factories in this country where experiments had been previously conducted. From the encouragement offered by this Act may probably be dated the really active modern period of the industry.

With the development of the factory has come the growth of other industries. When the Watsonville and Chino factories were built all the machinery had to be imported from Europe, Germany furnishing about $2,000,000 worth of machinery for four factories built during 1888 and 1891. The Yankee inventive genius of machinery men at once took hold of the matter, making so valuable improvements that both the above-mentioned factories were shortly refitted with machines of American make, and every factory in this country in the last few years has purchased American machines.

This small bounty, even for a brief time, was a wonderful stimulus to the struggling industry, and with a reasonable protection from the influx of cheap sugar from foreign ports this youthful industry will speedily reach the age of maturity and fulfill Napoleon's prediction when, in "Analyse de la Question des Sucres," he represents the beet as saying: "Respect me, for I enrich the soil; I fertilize the land, which otherwise would remain uncultivated; I employ the hands, which without me would remain idle; finally, I solve one of the greatest problems of modern society, I organize and increase labor."

RESULTS AT ALVARADO FACTORY.

The country from which the supply of beets is drawn for the Alvarado factory is one of the richest in the State. The soil is an easily cultivated sandy loam, largely subirrigated and very retentive of moisture, stretching from the bay eastward toward the hills for a distance of from five to ten miles. The climate is a peculiar one, and experience has shown it to be exceedingly well adapted to the development of a first-class beet. The planting season can be extended over a period ranging from February to well into May, thus securing a long campaign for the factory, which can usually begin operations in August and have consecutively-maturing crops of beets on which to work. The summers and the falls are generally dry and the winters mild, so there is little, if any, danger of the roots taking a second growth, and after harvest the beets need little protection. Few factories are so favorably located agriculturally as this pioneer in the industry. It is, perhaps, more certain of a reasonably good crop each year than any other factory in the State under the present conditions—unless we except the Watsonville factory—inasmuch as the precipitation (the average of which is 20 inches), even when it is deficient in the more southern areas, never falls below the point of maturing a profitable crop. The smallest average tonnage since 1888, 7.2 tons per acre, was secured in 1898, which is considered to have been the most unfavorable season since 1876–7. Again in 1900 the tonnage fell to about the same point, this also being a very dry year. Based upon the results of the last ten years the average percentage of sugar in the beets has been 13.66, and the average purity 81.7. On an average of over 3,000 acres annually there has been produced for thirteen years an average yield of 9.75 tons per acre, for which the factory has paid the farmer an average price of $4.60 per ton, thus giving a return of $46.54 per acre, including good, bad, and indifferent years. The crude sugar per acre has ranged from 3,864 pounds in 1896, when the rainfall was about 32 inches, to a minimum of 1,932 pounds in 1898, when the rainfall was but a little above 10 inches; thus showing what a great influence variations in climate from season to season may have upon the factory returns as well as upon the profit to the grower.

The season of 1901 was favorable, and from the 6,557 acres there was an average yield of 10.3 tons carrying 15.2 per cent sugar in the beet, with a purity coefficient of 81. The production of sugar from this factory was exceeded by only four factories in the country, two of these being in this State. The campaign lasted 128 days (August 19th to December 25th), during which time 67,251 tons of sugar beets were worked. It is interesting to note that from improved methods and machinery the cost of handling a ton of beets in the factory dropped from $5.28 in 1889 to $2.71 in 1897.

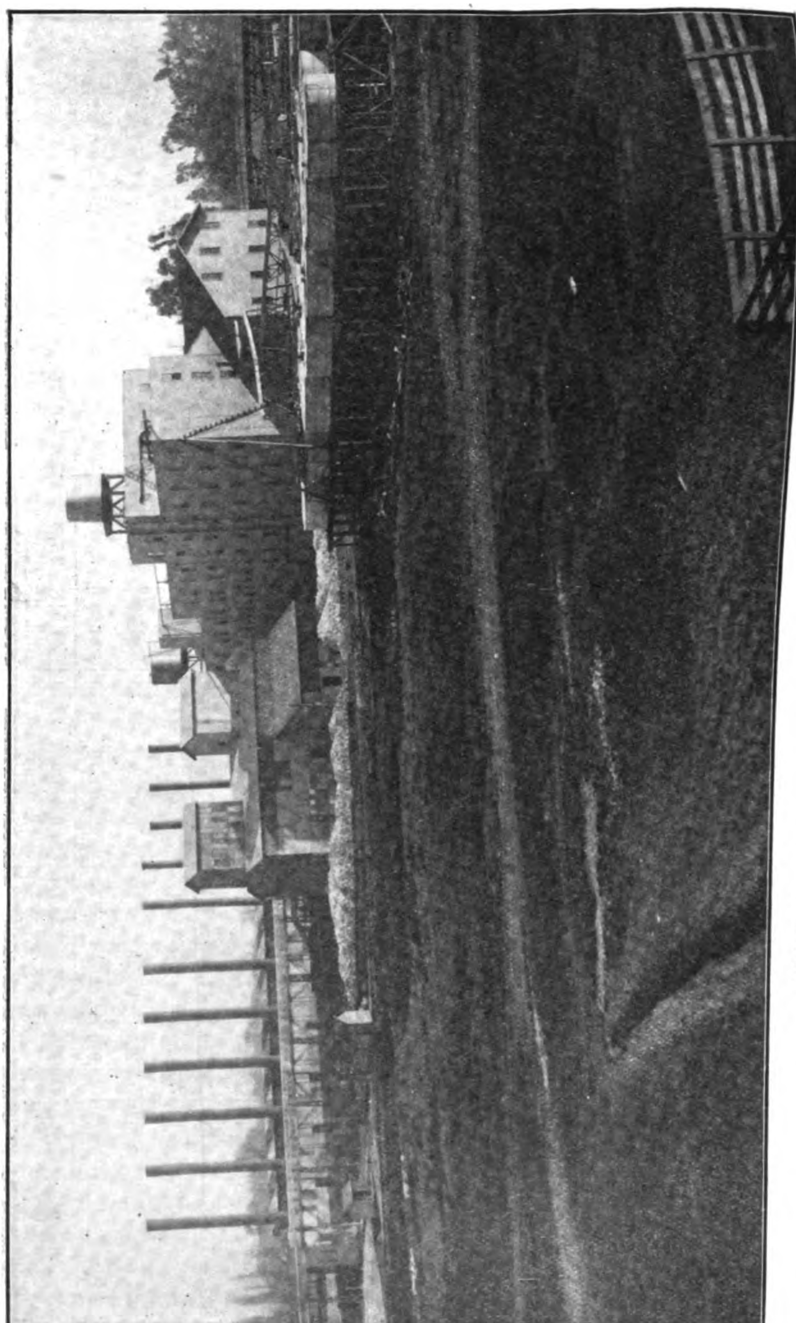


PLATE II. ALVARADO BEET-SUGAR FACTORY. CAPACITY, 900 TONS.

TABLE III.

ALVARADO FIELD AND FACTORY STATISTICS, 1889–1902.

Year.	Acres of Beets Grown.	Tons of Beets Produced.	Average Yield per Acre, Tons.	Average Price per Ton.	Total Paid for Beets.	Quality of Beets.		*Sugar.				Campaign.			Average Return per Acre.
						Sugar in Beets.	Purity.	Per Acre.		Per Ton.		Began.	Closed.	Days.	
								Total Crude.	Refined.	Total Crude.	Refined.				
1889	958	9,224	9.62	$4 54	$41,877	14.0	71.3	2,700	2,160	280	224	....	....	....	$43 71
1890	1,320	13,298	10.07	4 50	59,841	14.3	83.7	2,880	2,304	286	229	....	....	....	45 34
1891	949	10,942	10.47	5 00	54,710	12.0	80.0	2,420	1,936	240	192	....	....	....	57 65
1892	1,594	15,090	9.40	5 23	78,921	12.53	78.12	2,356	1,885	351	281	....	....	....	49 51
1893	1,843	20,272	11.30	5 09	103,185	14.51	83.89	3,179	2,543	290	232	....	....	....	55 98
1894	2,894	39,769	13.70	4 71	187,312	11.46	80.10	3,140	2,512	229	183	....	....	....	64 72
1895	2,401	27,385	11.40	4 14	113,374	13.41	80.50	3,038	2,430	268	214	....	....	....	47 22
1896	3,500	48,563	13.90	4 10	199,108	13.90	81.38	3,864	3,491	278	222	....	....	....	56 89
1897	4,829	49,002	10.10	4 17	204,338	14.54	85.75	2,936	2,349	291	233	....	....	....	42 31
1898	5,130	36,921	7.20	4 62	170,575	13.42	82.24	1,932	1,546	268	214	Aug. 29	Nov. 20	84	33 25
1899	5,344	36,740	11.00	4 55	167,167	13.16	78.78	2,894	2,315	263	210	Sept. 11	Dec. 2	82	31 28
1900	5,515	35,993	7.30	4 60	165,568	14.54	82.29	2,120	1,696	291	233	Aug. 27	Nov. 7	73	30 02
1901	6,557	67,251	10.30	4 60	309,355	15.15	84.02	3,120	2,496	303	242	Aug. 19	Dec. 27	128	47 17
1902	5,113	48,970	9.57	4 50	220,365	16.13	84.00	3,080	2,464	322	258	Aug. 19	Nov. 27	109	43 07
Total or average	47,947	459,425	9.70	$4 60	$2,075,696	13.70	81.5	2,788	2,220	283	226	....	....	....	$46 35

* NOTE.—The figures in the four columns under this heading are estimates made by the writer. The column headed "Total Crude Sugar" is based on the average yield per acre and the per cent of sugar in the beets. The column headed "Refined Sugar" assumes that 80 per cent of the total may be obtained as white granulated sugar. This would be considered good factory work when the molasses is not reworked, but is too low an estimate when such reworking is done.

The present season has not been quite so favorable for the crop as in 1901, and only about two thirds as many beets will be cut. During the present season the company has 5,300 acres in beets, about 750 acres of which is being grown by the company itself near Pleasanton, which furnishes the bulk of beets for the earlier part of the campaign, planting in that locality being possible in February.

The number of individual growers for this factory ranges from three hundred to five hundred. These farmers have come to know the crop and to need comparatively little instruction from the factory, with the exception of the newer growers, which may also be said of those about Watsonville, only to a little less extent, with which factory it is interesting to compare the results given above. Such a comparison is particularly interesting, as these are the longest records of any beet-sugar houses in this country and illustrate what may fairly be expected from favorably-situated and well-managed factories in humid regions. The two tables show a steady development of the industry and afford the most extensive data extant for judging of the "ups and downs" of this industry, both from the standpoint of the farmer and from that of the factory.

THE WATSONVILLE FACTORY.

As previously indicated, in 1888 Claus Spreckels had been won over to the importance of the beet as a sugar producer and the adaptability of California conditions to the industry, and in company with others, under the firm name of "The Western Beet Sugar Company," erected a factory at Watsonville, Santa Cruz County, in the rich Pajaro Valley, which was soon developed into the largest factory operated in the United States, and so remained until 1898. The country about this factory is one of exceptional richness in all the elements essential to the highest returns in beet culture. In the lower part of the valley a clay loam soil predominates, and higher up an adobe, which is succeeded by a dark red loam. The favorite soil for beets is the clay loam.

This factory was also fortunately located, and has been one of the most successful in the country, although, on account of its intimate connection with the cane refinery of San Francisco, it only manufactured raw sugar, and in this respect has differed from all other beet-sugar factories in this country. Since the erection of the larger factory near Salinas, in which Mr. Spreckels is also the principal owner, the Watsonville plant has remained idle, all beets grown in that region being shipped to the larger factory, which will doubtless continue to be the case until a sufficient acreage is obtained in the immediate vicinity of the larger plant.

The following tabular record of the factory operations for a period of ten years furnishes a large amount of valuable information:

TABLE IV.

WATSONVILLE FIELD AND FACTORY STATISTICS, 1888–1898.

Year.	Acres of Beets Grown.	Tons of Beets Produced	Average Tons per Acre.	Paid per Ton.	Total Paid for Beets.	Sugar Made.				Campaign.			Average Returns Per Acre.
						Raw, Tons.	Refined, Tons.*	Per Acre, Refined.	Per Ton, Refined.	Began.	Closed.	Days.	
1888	2,100	14,845	7.07	$4 83	$70,701	....	....	....	......	....	....	.....	$34 15
1889	1,778	13,472	7.58	4 95	66,686	....	....	....	......	....	....	.....	37 52
1890	2,900	18,715	6.13	4 44	84,095	2,127	1,946	1,341	9.6	Sept. 13	Dec. 4	82	27 22
1891	1,443	19,251	13.67	5 00	96,255	2,170	1,985	2,751	9.6	Sept. 15	Nov. 20	66	68 35
1892	4,254	54,415	12.79	5 00	772,075	5,695	5,211	2,450	10.4	Aug. 31	Jan. 23	146	63 95
1893	5,156	65,396	12.68	5 00	326,986	7,769	7,009	2,757	9.1	Sept. 14	Jan. 12	120	63 40
1894	11,013	143,802	13.05	4 87	700,316	12,047	11,023	1,998	12.9	Aug. 16	Mar. 24	220	63 55
1895	7,284	77,145	10.61	4 00	308,580	10,915	9,987	2,750	7.7	Sept. 3	Dec. 14	102	42 44
1896	11,017	154,936	14.06	4 00	619,744	19,528	17,868	3,243	8.6	Aug. 12	Jan. 29	170	56 24
1897	10,305	110,786	10.75	4 00	443,144	14,888	13,622	2,643	8.1	Aug. 29	Dec. 25	118	43 00
Total or average	57,230	672,763	10.84	$4 47	$2,989,576	9,392	8,594	2,442	9.3	....	....	128	$49 98

* Estimated by the writer at 100 lbs. raw sugar to 91⅓ tons of refined.

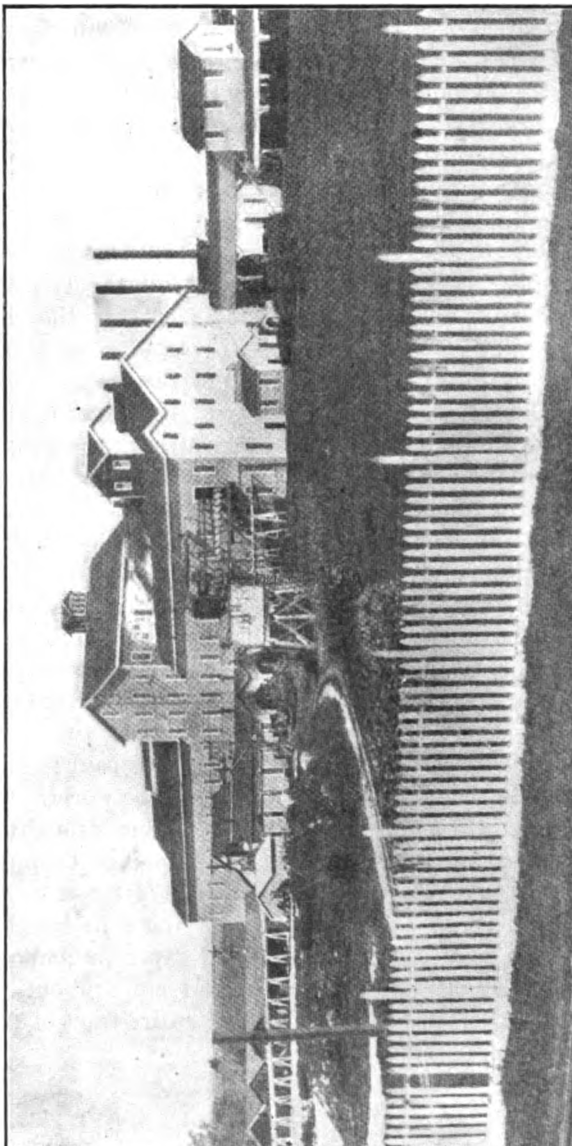


PLATE III. WATSONVILLE BEET-SUGAR FACTORY. CAPACITY, 1,000 TONS.

Including good, bad, and indifferent years, there has been an average yield of 11 tons during ten years on about 60,000 acres of beets, for which the farmers have received from $4 to $5 per ton. The returns per acre have ranged from $27 to $68, and averaged $50 for this period. As is usually the case, the profits from the crop during the first few years were small, on account of the inexperience of growers, but when once the most economical methods were learned and the land was put into an improved condition they were more than proportionately increased, and the crop proved one of the most profitable that the farmer could grow. This mill has paid nearly $800,000 in a single season for the crop.

It is interesting to note that the average of 8.9 tons of beets to make 1 ton of raw sugar is fully up to the record of the German factories for the same period, notwithstanding the fact that they have been so much longer in the business. The great variation of two succeeding years, from 7 to 12 tons of beets for 1 ton of raw sugar, while probably not altogether due to difference in quality of beets, yet must be considered as largely due to that factor, and illustrates what an influence upon the industry climatic conditions may have. The quantity of raw sugar per acre ranged from 1,466 pounds in 1890 to over 3,500 pounds in 1896, and averaged 2,700 pounds. It was in 1896, also, that the Alvarado factory secured its maximum of sugar per acre.

It is further interesting to note that the price of sugar decreased about 40 per cent during the period covered by the table, while the price paid for beets was not reduced to any material extent, and to-day, when sugar is lower than it has ever been, the price paid for beets remains practically the same.

The run of 220 days by this factory in 1894 is said to have been the longest campaign ever made by any factory in the world.

In 1898 this locality, like others, suffered from drought, but not to any great extent. As a result, however, the acreage dropped to 7,200, with a total yield of 57,761 tons, or an average of 8 tons per acre. The custom obtains here, as at Alvarado, of paying a flat price per ton for the beets, instead of using a sliding scale depending upon the sugar content of the beets. Yields of individual crops about Watsonville frequently run to 25 tons per acre, and an entire tract of 100 acres has given an average of 18 tons.

THE CHINO FACTORY.

A great impetus was given to the beet-sugar industry not only in California, but also in the United States, when in 1890 the Oxnard Brothers, who had previously been engaged in the refining business in the East, turned their attention westward, and established under the name "The Chino Sugar Company," their first factory at Chino, San

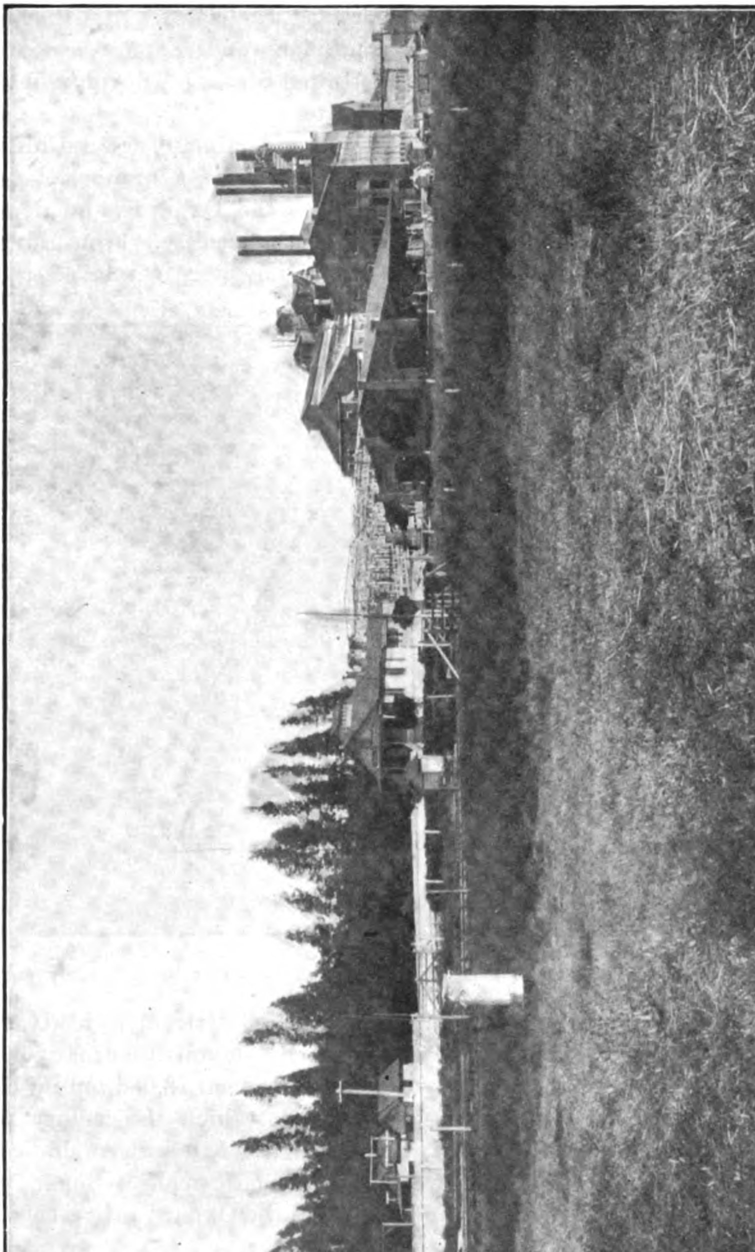


PLATE IV. CHINO BEET-SUGAR FACTORY. CAPACITY, 750 TONS.

Bernardino County, and followed this by the erection of others in Nebraska, and have since extended their operations to Colorado and Michigan. So vigorously have they pressed the business that they may be regarded to-day as the foremost champions of the sugar-beet cause, not only in California, but also in the United States. They now operate six factories, two of which are in this State.

To establish the adaptability of the soil and climate about Chino to the sugar beet, experiments had been conducted for a number of years with favorable results. These appealed to the Oxnards, and demonstrated the possibility of beet production in the locality. From a region devoted to cattle-raising, where but few people were employed, it has

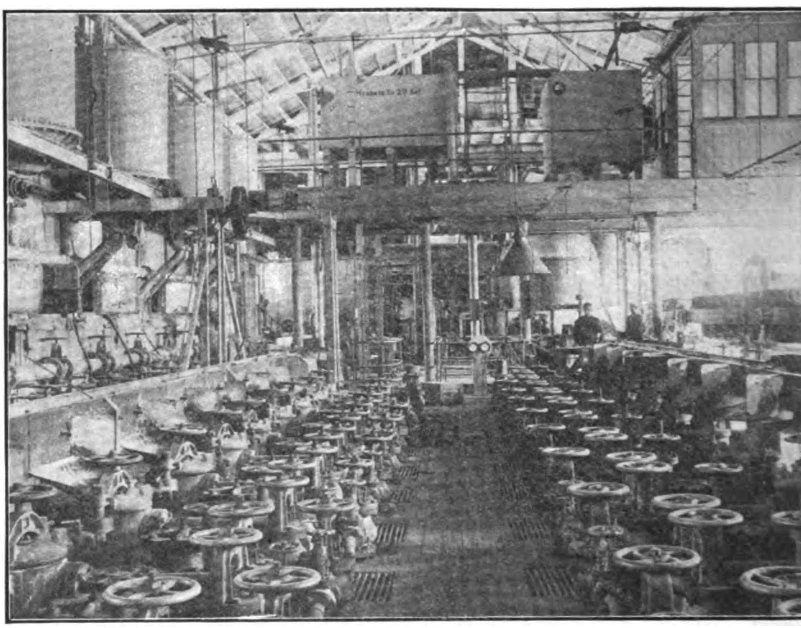


PLATE V. INTERIOR OF CHINO BEET-SUGAR FACTORY. SHOWING DIFFUSION BATTERY.

now changed to a thriving community of farms of from 10 to 40 acres, where many people have homes and furnish employment for many more. The first campaign of the factory was in 1891, when 13,086 tons of beets were received from 1,800 acres of land, for which the factory paid $51,035. This factory was continued under the name above indicated until 1898, when it was taken over by the American Beet Sugar Company, a company organized to include all of the Oxnard interest in beet sugar in the States previously named.

As in the case of Watsonville, the industry has been generally successful at Chino, excepting only the three years of exceeding drought. The region being so much farther south is more subject to drought conditions than those previously discussed, and greater precaution is necessary to retain the natural moisture in the soil. The average returns on 64,435 acres and covering twelve years have been over $40 per acre, and if the first two years in which the farmers were learning the industry and its adaptability to the different soils be excepted, the returns per acre have averaged near $45, which compares favorably with any other crop of the region. The mill has paid for beets as high as $430,000 in a single season. The average per cent of sugar has been 14.6, and the price $4.41 per ton. There has been an encouraging increase in the total acreage planted, especially when it is remembered that a rotation has been lately introduced and that dairying and alfalfa-growing have been carried on in the locality to quite an extent. The region has some difficulties to contend with in the way of black alkali and hardpan land, which is not the case in either of the localities previously described. These local peculiarities tend to accentuate any unfavorable moisture conditions, especially when beets are upon alkali soils.*

During the past season the conditions approximated the normal and there was a heavy tonnage. From 8,822 acres harvested 97,605 tons of beets were produced, an average of 11 tons per acre. Of the total acreage the company itself grew about 400 acres. The sugar content in this region is never high, but quite constant; and the purity is generally lower than in the other localities, which may probably be traced to the higher per cent of soluble salts in the soil.

The beets immediately about Chino are grown for the most part without irrigation, but about Anaheim and Compton, which furnish about 1,000 acres, irrigation is practiced to a greater or less extent.

It does not appear that what falling off there has been in the acreage contracted by individual farmers has been due to any particular dissatisfaction with the crop, but rather to a combination of circumstances, some of which may even indicate a more healthy condition of the country and may ultimately lead to a greater stability of the industry. The causes leading to this may be named in order of importance, as follows:

(1) A series of dry years, which affected, as indicated previously, all sections of the State, but most seriously of all the portion south of Tehachapi.

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*The unfavorable effects of soluble salts, especially common salt, upon the sugar content of beets, are well understood in Europe, and soils showing any obvious symptoms of salinity are excluded from sugar-beet culture. Experiments at the Chino substation tract have shown that the alkali of that region, mainly sulfate of soda, is not nearly as injurious to the sugar content as common salt; so that very satisfactory roots have been produced on land which, according to European views, would be held as wholly unadapted to sugar-beet culture. While unquestionably the sodic sulfate is less injurious than common salt, climatic factors also come to the aid of the sugar beet, in that at the time of sugar formation the alkali salts are out of the reach of the active absorbing rootlets; being accumulated within a few inches of the soil surface by evaporation, while the subsoil is almost free from salts.—E. W. H.

TABLE V.

CHINO FIELD AND FACTORY STATISTICS, 1891-1901.

Year.	Acres of Beets Grown.	Tons of Beets Produced.	Average Yield per Acre, Tons.	Average Price per Ton.	Total Paid for Beets.	Sugar in Beets, Per cent.	* Sugar. Per acre of Beets. Crude, lbs.	* Sugar. Per acre of Beets. Refined, lbs.	* Sugar. Per ton of Beets. Crude, lbs.	* Sugar. Per ton of Beets. Refined, lbs.	Campaign. Began.	Campaign. Closed.	Campaign. Days.	Average Return per Acre.
1890-91	1,800	13,086	7.21	$3 90	$51,035	13.2	1,903	1,522	264	211	Aug. 20	Oct. 31	73	$28 35
1891-92	3,693	26,368	7.14	4 26	112,328	14.5	2,070	1,656	290	232	July 15	Oct. 11	91	30 41
1892-93	4,887	50,238	10.28	4 19	210,497	13.2	2,712	2,170	264	211	July 31	Nov. 4	97	41 02
1893-94	4,778	44,530	9.32	4 57	203,502	14.4	2,684	2,147	288	230	Aug. 2	Oct. 24	85	42 59
1894-95	7,730	85,578	11.07	4 23	361,994	14.5	3,210	2,568	290	232	July 9	Nov. 14	129	46 83
1895-96	7,348	64,001	8.71	3 83	245,124	14.3	2,491	1,993	286	229	July 30	Oct. 27	90	33 63
1896-97	10,486	97,214	9.27	4 44	431,630	15.4	2,854	2,283	308	246	July 17	Dec. 10	146	41 16
1897-98	5,339	46,770	8.76	4 56	213,271	15.1	2,644	2,115	302	242	Aug. 16	Nov. 5	79	39 75
1898-99	2,525	*a* 50,226	4.05	5 40	55,220	*d* 17.4	1,409	1,127	348	278	Aug. 26	Oct. 30	66	21 47
1899-1900	1,230	*b* 4,157	3.38	4 15	17,251	14.5	980	784	290	232	July 25	Sept. 6	42	14 02
1900-01	5,797	*c* 48,579	8.38	5 03	244,352	14.2	2,378	1,902	284	227	Aug. 2	Dec. 1	120	42 14
1901-02	8,822	97,605	11.06	4 36	427,509	14.2	1,386	1,109	284	227	....	....	......	48 22
Total or average	64,435	588,352	8.22	$4 41	$2,674,713	14.6	2,400	1,920	292	233	....	....	......	$41 51

a In addition, received from Oxnard 34,510 tons.
b Did not operate; beets shipped to Oxnard.
c Of which 24,662 tons were shipped to Oxnard.
d Including 34,510 tons of Oxnard beets, weight included in average.
* Estimated by the writer.

(2) The introduction of a three-year system of rotation: beets, barley, and rape, the latter being introduced as a green-manure crop.

(3) The encroachments of dairy farming and alfalfa-growing.

The first is a condition which may well demand the serious consideration of the sugar people, and will be discussed in another portion of this series.

The other two factors in reducing the individual acreage may probably be looked upon as a sign of advancement in the region, which will ultimately redound to the interest of the beet-sugar industry by keeping the land in better condition and introducing another industry that will work very closely with it.

THE LOS ALAMITOS FACTORY.

The Los Alamitos Sugar Company was organized in 1887 by W. A. & J. Ross Clarke, of Butte, Montana. The factory was built and made its first sugar in the same year. Los Alamitos is located about thirty miles southeast of Los Angeles. The Bixby Land Company, who were, and still are, the principal land-owners in the region, contracted to supply the sugar company with beets for a series of years. The capacity of the factory for the first campaign was 350 tons per day, but in 1898 it was increased to 700 tons. The factory is substantially built after the Dyer pattern, and is well equipped for the successful and economical manufacture of sugar. The soil of this locality at the time of the location of the factory was in a virgin condition and had been little used, except for the production of grass for pasturage. In the first year 3,000 acres were broken and put into beets. Within six months a town of five hundred people with comfortable homes sprang up about the factory.

The first campaign was a successful one in every sense, 29,542 tons of beets, with a sugar percentage of 15.73 and a purity of 82, coming from 2,800 acres of land, or an average of 10.5 tons per acre. From these was made a little over 6,000,000 pounds of granulated sugar, or 2,143 pounds per acre. The average returns per acre were $43.68. During this first season a number of crops ran over 20 per cent sugar in the beet.

The subjoined table shows the tons of beets and their quality for the several years the factory has operated:

TABLE VI.

STATISTICS OF LOS ALAMITOS FACTORY.

Year.	Tons of Beets Cut.	Sugar in Beets.	Purity.	Length of Campaign.
1897	29,542	15.73	81.99	120 days.
1898	2,884	15.08	79.65	7 "
1899	11,086	16.48	82.60	29 "
1900	7,501	17.55	82.18	31 "
1901	56,005	17.08	82.80	181 "
1902	42,000	16.90	82.00	....

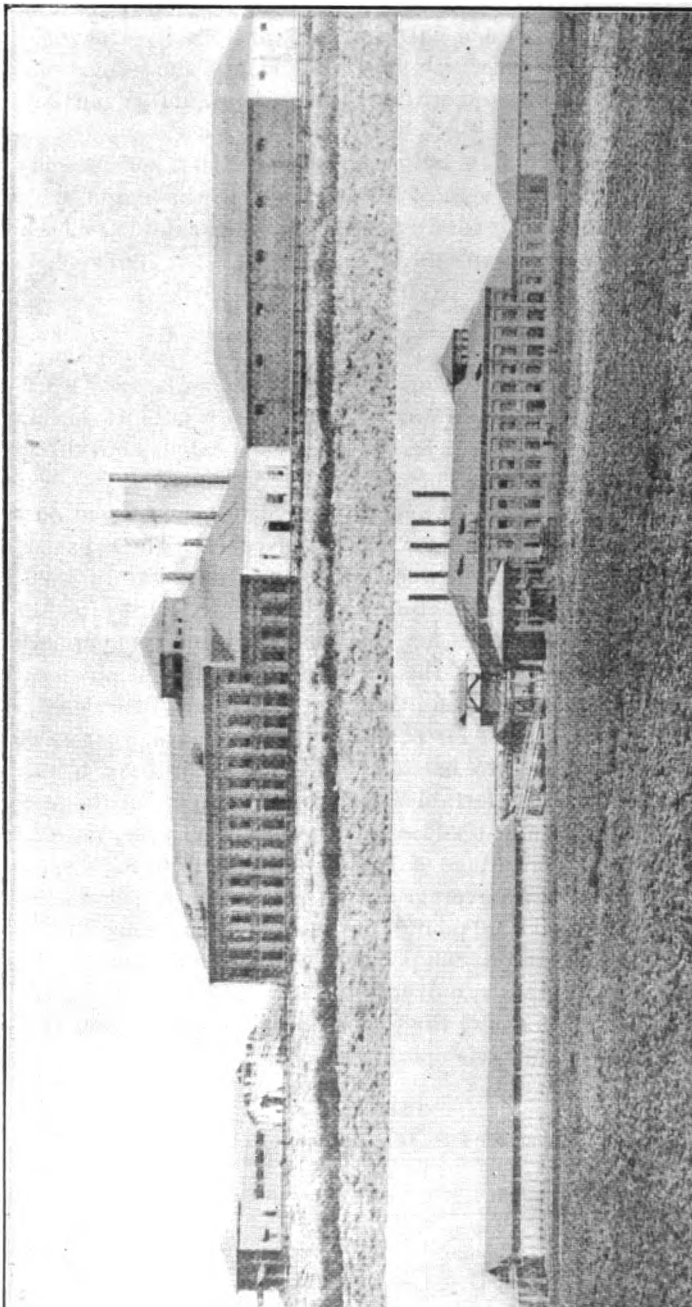

PLATE VI. LOS ALAMITOS BEET-SUGAR FACTORY. CAPACITY, 700 TONS.

During the drought period of 1898–1901, this factory suffered perhaps more heavily than any other in the State except one, which may partially be accounted for from the fact that the industry was entirely new in the region and the beets were not planted on the more moist land in all cases, and all beets located on the more sandy soils were ruined. The results at this factory have not been as encouraging as might be expected had attention been given to securing a water supply for irrigation of the crop. Notwithstanding the success that has attended the growing of beets by irrigation in Utah and Colorado, there seems to be something of an antipathy to the practice in this State; but to one unprejudiced in the matter it would seem to be the essential factor for permanent success in this industry, at least in the southern part of the State. At present the governing conditions for a crop in this locality seem to be a rainfall of from 8 to 10 inches in January, February, and March, and so distributed that there is practically no "run off." In 1898–1900 these conditions were far from being realized, which resulted in a greatly reduced crop.

The 56,005 tons of beets cut in 1901 were produced on 6,000 acres of land, thus giving an average yield of 9.3 tons per acre, with an average sugar content of 17.2 and a purity coefficient of 82.5, which brought an average price of $4.50 per ton, or a total of $252,000 paid to the farmers for the crop. The average returns per acre were $41.85; the granulated sugar produced per acre 2,000 pounds, 1 ton of beets yielding 214 pounds of sugar. In 1902 the results were not quite equal to those of 1901, in either quality or quantity of beets. The average return from 5,900 acres was $38.50 per acre and 16.9 per cent sugar in the beet.

In the intermediate years between 1897 and 1901 the acreage grown and the yield per acre were quite small, because of the drought, and should not be taken as a fair index of what the locality can do in beet production. The figures plainly show that high-grade beets can be produced; but unless the moisture conditions can be rendered certain the crop is likely to be an uncertain one in this locality. For this reason a strong and united effort on the part of both growers and manufacturers should be made to develop to the greatest extent possible the abundance of artesian water which evidently lies at the comparatively small depth of from 300 to 600 feet. Already the Bixby Land Company has some twenty-five flowing wells upon its land, and is preparing to irrigate extensively. With the introduction of an extensive irrigation practice investigations should be made as to the best methods for the application of water, for some of the lands are inclined to be quite alkali in character, and unless attention be given to this phase trouble may be experienced from the rise of alkali. Beets should be kept on the more moist lands, avoiding, so far as possible, the more sandy soils. An increase of humus in the soil is also desirable, and the introduction of green-manure crops in alternation with beets would materially improve the conditions for beet culture by rendering the soil more retentive of moisture. These matters will be more fully discussed in Part II of this series.

THE CROCKETT FACTORY.

The next factory erected in California was at Crockett, Contra Costa County, by the California and Hawaiian Sugar Refining Company. The factory has a capacity of 1,200 tons of beets per day. The company devotes the principal part of the year to the refining of cane sugar brought from the Hawaiian Islands. Its supply of beets is not drawn from the immediate locality of the factory, but from lands owned or leased by the company, which at present grows practically its entire supply in several widely separated regions, viz: Bethany, San Joaquin County; Suisun and Cordelia, Solano County; Reclamation, Sonoma County; and Concord and Osage, Contra Costa County.

The factory, having been built in 1897, has had nothing like a fair field for securing normal results until 1901. The results of the 1900 and 1901 campaign are shown below:

TABLE VII.

RESULTS AT CROCKETT, 1900–1902.

	1900.	1901.	1902.
Campaign began	Aug. 1	Aug. 15	Aug. 15
Campaign ended	Oct. 15	Nov. 10	Nov. 6
Days of actual operation	15	86	82
Acres of beets planted	5,800	....	....
Acres of beets harvested	2,500	5,183	5,046
Tons of beets worked	8,704	25,112	36,884
Average yield, tons	3.5	4.8	7.3
Average sugar content of beets, per cent	19.4	17.5	19.6
Average purity of juice, per cent	81.6	80.9	83.2
Sugar produced, tons	1,328.7	3,083	*5,870

* Estimated by the writer.

While in 1901 the conditions were somewhat adverse to the highest crop production, the poor general showing in that year may be largely accounted for by the selection of land at the outset which was either poorly adapted or entirely unadapted to the crop. Much of this has since been replaced by better land, and in 1902 the crop was much improved, as can be seen from the table. The experience of this company in the production of beets is a standing example for those who may enter the industry later, that it is not every locality which is adapted to the production of sugar beets, however good shallow-rooting crops it may produce.

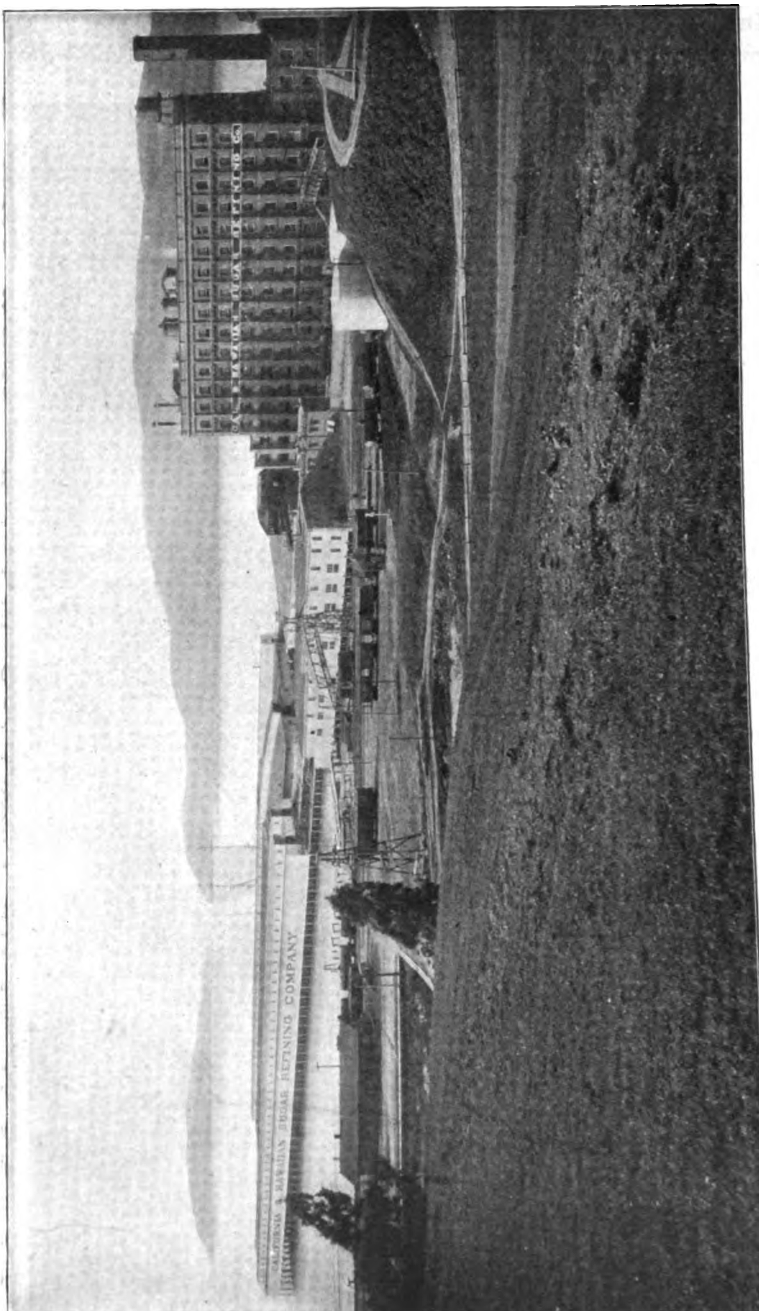

PLATE VII. CROCKETT BEET-SUGAR FACTORY. CAPACITY, 1,200 TONS.

THE OXNARD FACTORY.

In 1897 the Oxnards, under the name of the "Pacific Beet Sugar Company," began the erection of a 2,000-ton plant at a small town now

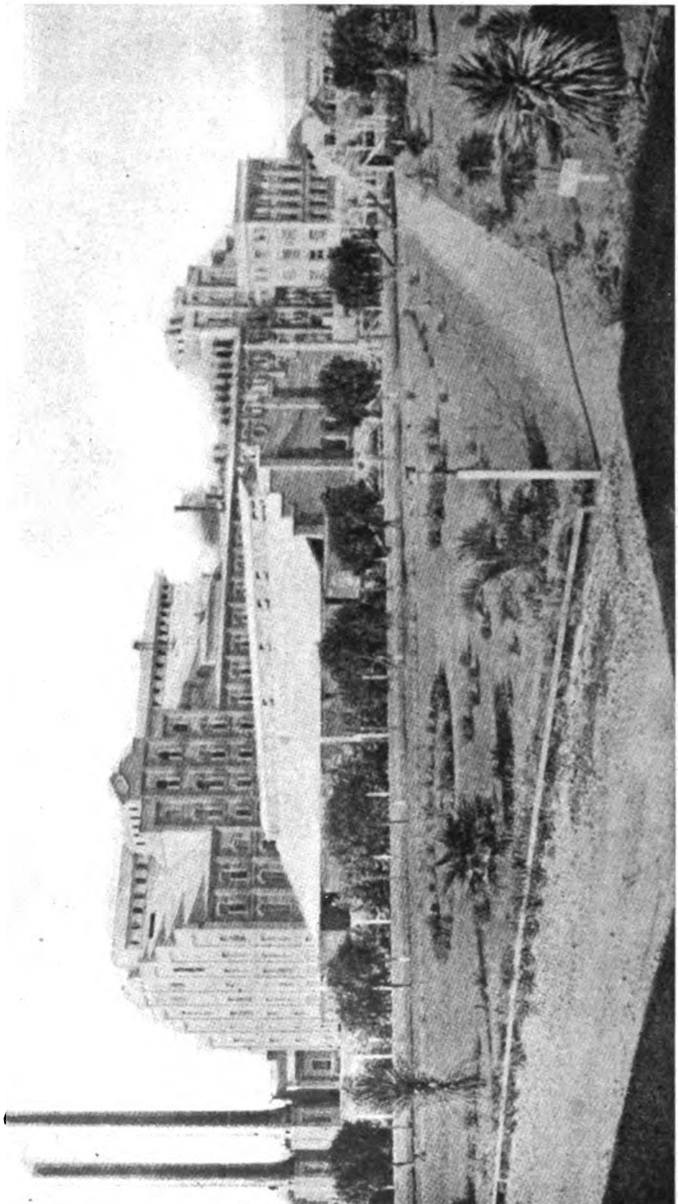

PLATE VIII. OXNARD BEET-SUGAR FACTORY. CAPACITY, 2,000 TONS.

called Oxnard, in the Santa Clara valley of Ventura County, some three and a half miles from the ocean, which town was called into being by reason of the factory being located there, and now bids fair to become a model city with all modern improvements.

With the organization of the "American Beet Sugar Company," which took all the factories operated by the Oxnards, this factory passed to that company and is now operated by the former.

Ventura County lies along the coast north and west of Los Angeles and east of Santa Barbara. The region is noted for the fertility of its soils, which in numerous instances have been cropped steadily for thirty years without fertilization and are still producing remunerative

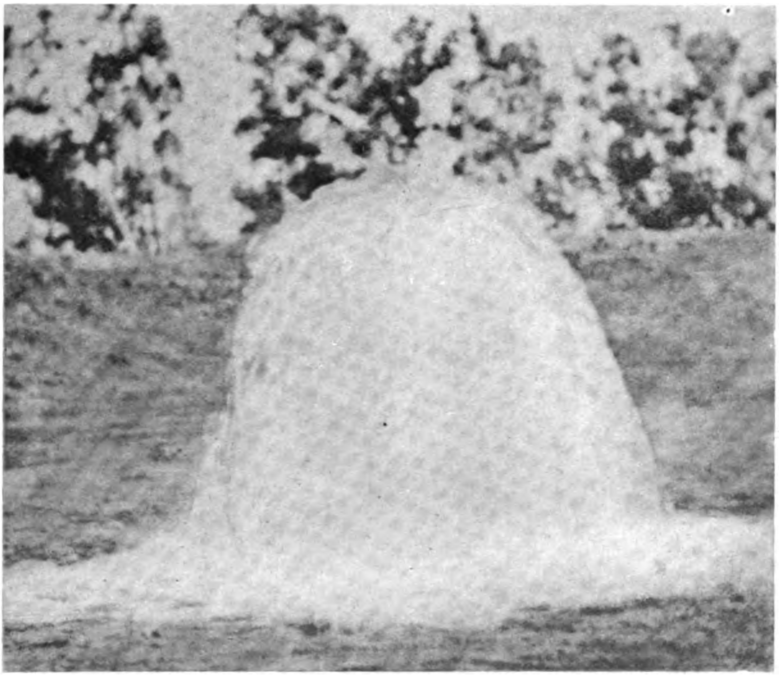

PLATE IX. Artesian Well at Oxnard.

returns. Along the streams which break the generally rugged surface of the county, nestle many small valleys, some high and broken, others low and level, but all fertile. The climatic conditions of the valley are somewhat unique. In general the land is only a few feet above the level of the sea, and the physical characteristics of the soil are such as to render them very retentive of moisture precipitated during the winter months, and lying so close to the sea the natural humidity of the air reduces evaporation to a minimum. Heavy night fogs are the rule during the growing season, which serve in a measure to replace the little evaporation that does take place. The rainfall has usually been sufficient for the profitable cultivation of crops without resorting to irrigation. The heaviest precipitation during a period of twenty-seven years was 38.4 inches, in 1884; and the lightest, 5.84 inches, in 1898. The normal is about 16 inches. The temperature is equable, the range for the growing season being 34° to 63°.

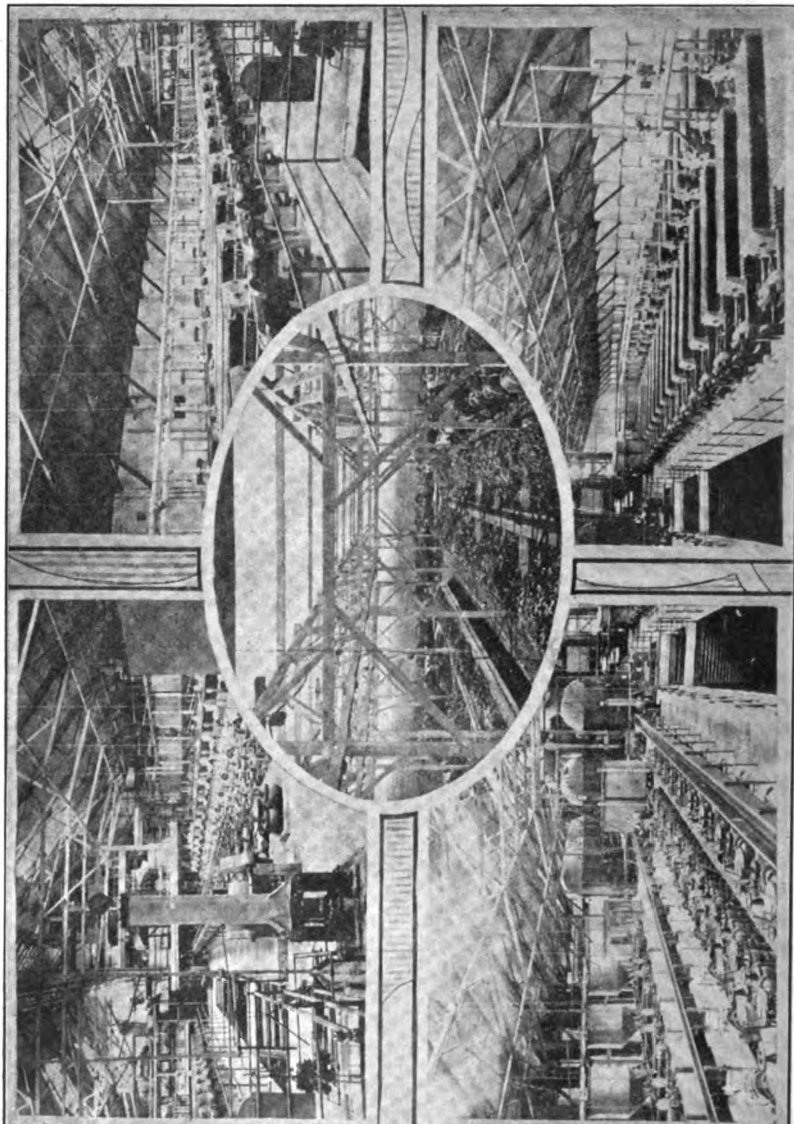

PLATE X. VIEWS IN THE INTERIOR OF OXNARD BEET-SUGAR FACTORY.

Should future experience show the rainfall to be too uncertain for the crop, the ease with which flowing artesian water can be reached at from 130 to 250 feet will solve the problem of an abundant water supply that will render the farmers independent of rainfall.

Along the shore and close to the streams the soil is a light sandy loam, and on the low-lying mesas is inclined to a heavy clay. Between these two extremes are found all intermediate grades. In general, the soil can be called a medium sandy loam, rich and deep.

It is considered by the company that there are some 60,000 acres of good beet land tributary to this factory within a radius of twenty-five miles, of which about 20,000 acres are considered first class (capable of producing 15 tons or over per acre); 25,000 acres second class (capable of producing 8 to 12 tons per acre); the balance as third class, some of which is light sandy soil, somewhat alkali in character—in some cases gravelly—but which, properly handled and in favorable seasons, will give good returns if planted to beets. The better class of land is valued at from $150 to $300 per acre; the second class at from $100 to $150; and the lighter soils at $75. The rental of land for beet-growing ranges from one fifth to one third of the crop, depending upon its character. In addition to sugar beets, the principal crops are lima beans, grain, alfalfa, and English walnuts.

The value of irrigation not only for beets, but also for other crops, is rapidly being realized, notwithstanding the usually fair moisture conditions of the region, and some experiments have been tried in the irrigation of beets down the rows, as practiced in Utah for years and in Colorado for a less time, with so much success. The experiments proved very successful, bringing an increased yield of 3 to 4 tons per acre. It is anticipated that the method will be largely increased. In the opinion of the writer, based on wide observation and experience, it is the only method of applying water to the beet crop that will meet with favor for any length of time, as giving the highest returns in yield and ease of cultivation. On land properly prepared it is remarkable as to the rapidity with which the work can be done. Farmers growing beets within a radius of the Santa Clara ditch system, or within the range of an artesian well, should avail themselves of a trial of this method, and can rest assured that the effect will abundantly repay them.

For a further discussion of this subject the reader is referred to Part II of this series, which will appear later.

The factory is well called the "Model beet-sugar factory of America," for while it may be surpassed in capacity it certainly is not in perfection of appointment. Under one colossal roof can be found machine and repair shop, engine-room, lime-grinding mills, an electric plant, ice manufactory, and scale and store rooms, all accessory to the main work of sugar manufacture. The beets are received in four parallel sheds or bins of regulation form, each 350 feet long and holding 1,000 tons each. The beets are unloaded by means of nets, on which, resting in the wagon, the beets are placed in the field. At the factory the nets are grasped on one side by iron hooks attached to a beam above, and by means of block and tackle connected with power, the beets are bodily dumped into the bin. The main building of brick rises 93 feet above the foundation and extends 400 feet in length. Connected with the main building by a corridor is a fine three-story edifice, in which are located the offices and extensive laboratories.

In the boiler-house, 100 by 300 feet, at the rear of the factory proper, are twenty-eight steam boilers—eight high-pressure and twenty low-pressure—of 7,000 horsepower, burning crude oil as fuel; this is supplied to them through iron tanks located some 230 yards away, and which hold 30,000 barrels each.

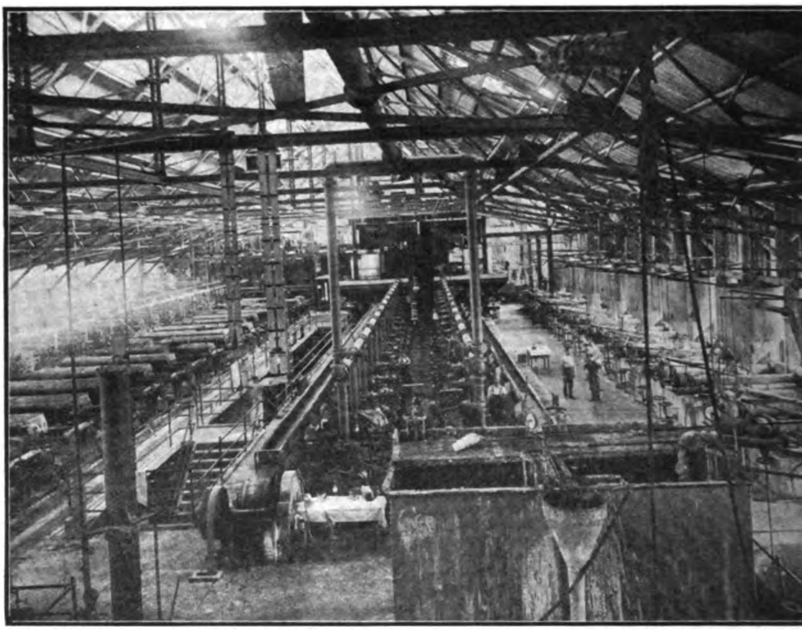

PLATE XI. INTERIOR OF OXNARD BEET-SUGAR FACTORY.

At the rear of the factory and connected with it are two immense limekilns, one rising to a vertical height of 95 feet, for burning limestone, and the other a revolving horizontal kiln for reburning lime from the factory. The vertical kiln and the twin steel smokestacks, each 36 feet in circumference and 154 feet high, stand as imposing landmarks for miles around.

The factory was intended to work the crop of 1898, but owing to the drought of that year the company decided to ship the beets to Chino, and the factory did not make its first campaign until 1899.

TABLE IX.

RESULTS AT OXNARD, 1897, 1900–1902.

	1897.	1900.	1901.	1902.	Average or Total.
Acres of beets harvested	11,442	6,238	11,392	17,690	46,762
Tons of beets produced	*a* 94,902	*b* 63,010	*c* 139,484	*d* 176,512	483,908
Average yield per acre, tons	8.30	10.12	12.23	9.98	10.2
Total amount paid farmers for beets	$438,447	$190,558	$673,708	$849,022	$537,934
Average price per ton	$4 62	$4 77	$4 83	$4 81	$4 77
Sugar in beets, per cent	17.5	17.8	16.4	15.8	16.9
Purity coefficient	81.6	81.0	82.7	79.8	81.2
*Crude sugar per acre, lbs	2,904	3,603	2,006	3,164	2,919
*Refined sugar per acre, lbs.	2,323	2,882	1,605	2,531	2,335
*Crude sugar per ton of beets, lbs.	350	356	328	316	337
*Refined sugar per ton of beets, lbs.	280	285	262	253	270
Campaign began	Aug. 8	Aug. 15	July 11	July 19	....
Campaign closed	Oct. 17	Oct. 18	Nov. 9	Dec. 1	....
Length of campaign, days	61	65	122	134	....
Average returns per acre	$38 35	$48 26	$59 08	$47 90	$48 19

a Of which 31,510 tons were shipped to Chino.
b In addition to which we received from Chino 4,154 tons.
c In addition to which we received from Chino 24,376 tons.
d In addition to which we received from Chino 12,206 tons.
* Estimated by the writer.

A particular point to note here is the very high average sugar percentage. The company, at present, pays upon a sliding scale, the price depending upon the sugar content of the beets, and in consequence a small yield in tons is usually offset by a richer beet, which brings a larger price per ton, provided always that this lessened tonnage has not resulted from a too scattering stand or from a diseased condition of the beets.

For the four years the factory has been in operation the average yield has been 10.16 tons per acre on 46,769 acres, and the average price per ton $4.77, thus giving an average return per acre of $48.19, and it will be remembered that this period includes two of the so-called "dry years." The crop for 1902 gave a total of more beets, but not so large an average yield as in 1901. Still the returns per acre were fair, when measured by most other farm crops.

THE SALINAS FACTORY.

While the erection of the immense plant near Salinas, at a place now known as Spreckels, by the Spreckels Sugar Company, which also controls the Watsonville factory, was begun in 1897, it, like the Oxnard factory, did not operate until the following year, the beets being worked at Watsonville. California is noted for doing things on a large scale, and in keeping with this, Mr. Spreckels has erected here the largest beet-sugar house under one roof in the world. The factory has a total rated capacity of 3,000 tons of beets per twenty-four hours. It practically consists of four sets of machinery under one roof. The factory itself is a model of mechanical ingenuity, and while the plant at Oxnard was erected in the same year, yet this factory represents an entirely different type of construction.

Of more than passing interest on account of its size, it demands a brief description:

The main building is of steel and brick construction, 582 feet long, 102 feet wide, and five stories high. It is divided into three parts, the beet end of the house containing the four beet-screws, beet-washers, four beet-elevators, four beet-scales, eight cutters, fifty-six diffusion cells, in four batteries of fourteen cells each, four weighing tanks, five first saturation tanks, four second saturation tanks, filter presses, and the various heaters and pumps.

In the center of the building are the two sets of immense quadruple-effect evaporators, side by side, with an additional set of double-effect evaporators, while in the sugar end are found the vacuum-pan tanks, the seven 14-foot vacuum-pans, 28–48 inch centrifugal machines, forty-nine crystallizers, seven mixers, three sugar-hoppers, nine sugar-packers, nine sugar-conveyors, nine sack-conveyors from the scales to the railroad platform, all automatically handled.

The engine-room occupies the central part of the immense building on the ground floor, and contains five vacuum pumps (flywheels 20 feet in diameter), two gas pumps (flywheels 20 feet in diameter), six sugar pumps, one beet engine (400 horsepower), one centrifugal engine (400 horsepower), four electric generators direct-connected (two of 400 horsepower and two of 700 horsepower).

Situated next to the main building on the east is the boiler-house, 559 feet long, 68 feet wide, and 32 feet high. Here are to be found forty-eight water boilers of 125 horsepower each, four economizers, two limekilns (14 feet diameter, 50 feet high), four gas washers, one lime elevator, three lime mixers, two lime settling-tanks, one lime pump for milk or lime, four feed pumps for 160 pounds pressure per square inch; and connected with this immense boiler plant are the two steel stacks, each 216 feet high and 13 feet in diameter, each stack weighing, with its brick lining and base, 1,000 tons.

Next comes the machine shop, carpenter shop, and storeroom, 559 feet long, 40 feet wide, 32 feet high. The three buildings are of fireproof construction throughout; no woodwork except the sheathing underneath the slate on the roof. All floors are made of concrete.

The fuel used is oil, of which 1,200 barrels are consumed every twenty-four hours.

Two oil tanks are provided for storage, each 77 feet in diameter by 25 feet high, each having a capacity of 20,000 barrels or 850,000 gallons.

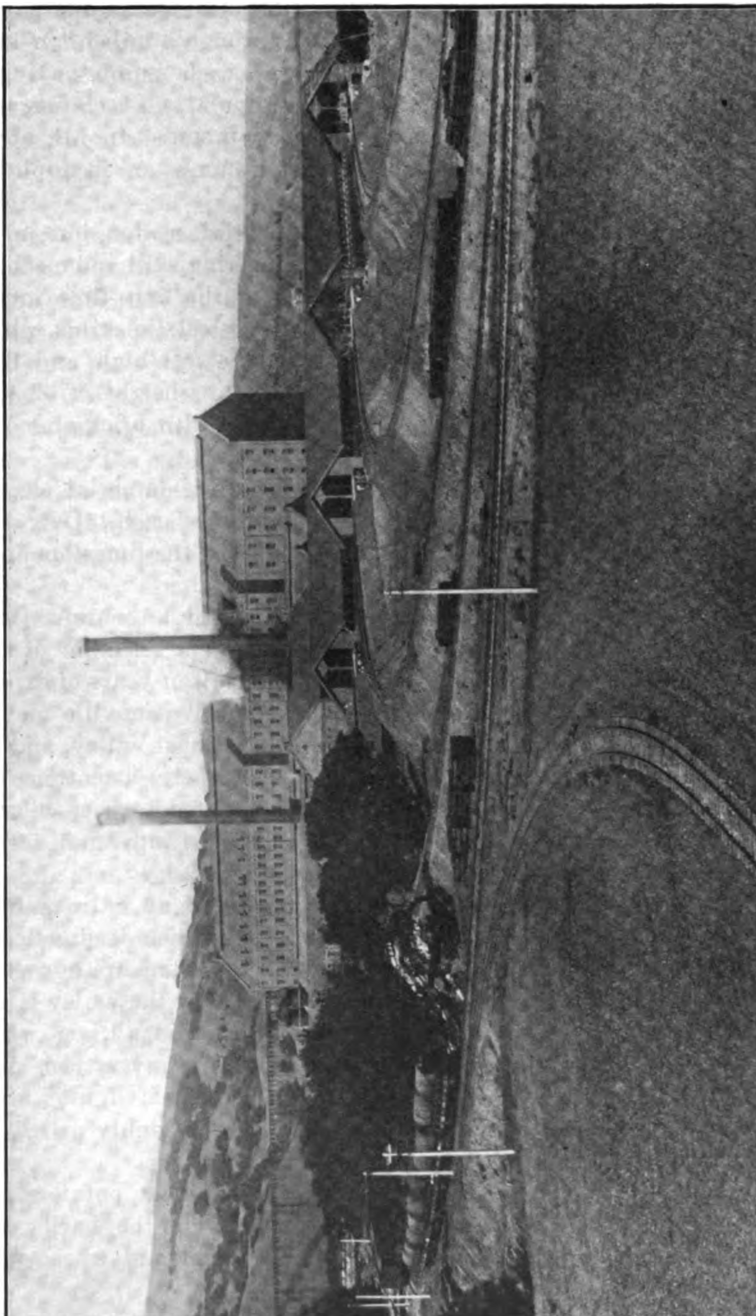

PLATE XII. SPRECKELS BEET-SUGAR FACTORY AT SALINAS. CAPACITY, 3,000 TONS.

Water is provided partly from six wells, 48 inches in diameter and 160 feet deep, each giving an abundance of beautiful clear water, and partly from the Salinas River, whence it is pumped through a mile of 32-inch steel riveted pipe by two centrifugal pumps, each pump having a capacity of 10,000,000 gallons per twenty-four hours, and each operated by a 200 horsepower direct-connected electric motor. In all, about 13,000 gallons is the daily consumption, though pumps are in duplicate and can handle twice that quantity.

At the extreme end of the boiler-house, in a third section, but under its roof, has been erected an innovation in engineering skill and mechanical work, which is in operation in Salinas for the first time in the world. This new idea consists of two enormous steel limekilns, which stand upon an open iron framework base, some 4 feet high, and then tower up through a circular opening in the roof to a height of 52 feet. These kilns are 15 feet 6 inches in diameter, lined with brick and concrete.

Thirty feet above the kilns, or 86 feet in the air, is an aërial electric railway, 640 feet long, supported by spans of 140 feet each. Over this railway, in buckets of five-ton capacity, is conveyed the limestone from the river bank to the top of the kilns.

The country tributary to this factory is estimated to contain about 90,000 acres suitable for the production of beets. The selection of this valley as a site for this immense plant was the result of years of experimenting on the part of Mr. Claus Spreckels. The Watsonville factory had for years received many beets from the Salinas Valley, and on account of the generally excellent results from there, attention was directed toward it as being exceedingly well adapted to beet culture. Vast tracts were purchased and have been subdivided into small farms, which are leased to growers on the share system.

The great Salinas Valley, some 15 miles wide at Salinas City, embraces about 640,000 acres of agricultural land, which is practically all of the arable land in Monterey County. Of this there are now some 185,000 acres under cultivation. In point of fertility the valley is not surpassed by any other in the State. Along the Salinas River, which traverses the valley, and the other streams, the soil is a very rich dark alluvium, which farther back gives place to a somewhat lighter loam, very deep and easily worked; then come tablelands highly prized for grain culture; and finally the uplands.

Until the introduction of beet culture, barley, wheat, potatoes, and white beans were the principal crops of the region, the barley and potatoes being principally grown upon the lower land and wheat upon the benchland.

In a continuous record of twenty-eight years, the temperature has never reached 100° as a maximum, nor has it fallen below 20° as a minimum. The rainfall is normally 13.50 inches, practically all coming in December, January, and February. Sometimes it is over 20 inches, and has reached as high as 27 inches. The moisture conditions here also include heavy sea fogs, but in a somewhat less degree than at Watsonville and Oxnard.

The soil is rich in humus and very retentive of moisture. On this account and because the rainfall is generally sufficient to mature a crop, irrigation has not been much practiced, but, as at Oxnard, is bound to become a factor in beet-growing, and in a crude way is even now being more or less resorted to in a few cases.

The officials of the company declined to give the figures upon which to base tables similar to those which have preceded, and the writer has, therefore, been obliged to seek such information as possible from other sources which he deemed reliable. It is believed that the data given are to be relied upon as giving a very close idea as to the capabilities of the region and the extent of the industry which has been developed.

Several smaller valleys leading off from the larger one furnish many beets for this great factory; for example, in 1901 and 1902 beets for the factory were received as follows:

	1901.	1902.
Salinas Valley	141,280 tons	96,543 tons
Pajaro Valley	85,910 "	59,747 "
San Juan Valley	27,620 "	31,574 "
Santa Clara Valley	16,512 "	10,184 "
Totals	271,322 "	197,948 "

The beets in 1901 averaged 16.5 per cent sugar, purity 82.5, and brought $4.50 per ton at the factory, or $1,153,118, and from them was made about 57,400,000 pounds of sugar. The campaign began September 5th and continued until January 8th—122 days. The average yield was 13.8 tons per acre, giving a return of $62.10. Estimating the sugar per acre and per ton in the same manner as in the former cases, we have:

Crude sugar per acre	4,400 lbs.
Refined sugar per acre	3,520 "
Crude sugar per ton of beets	330 "
Refined sugar per ton of beets	264 "

The tonnage for 1902 was 197,948 from 17,530 acres of land, from which was made 21,607 tons of sugar, the price for beets being $4.50 per ton. The campaign extended from September 9th to December 22d.

In the first campaign the factory sliced about 175,000 tons of beets, but in 1900 the crop was damaged by drought, and still more seriously injured by a disease of the plants, which is supposed to have been induced by the exceedingly dry weather of that season.

THE BETTERAVIA FACTORY.

The last factory built in the State was by the Union Sugar Company at Betteravia, a town in the Santa Maria Valley, Santa Barbara County, called into existence by reason of the location of the factory there, in the dry year of 1899. The company was organized by the same parties interested in the Alvarado factory. The factory has a rated capacity of 500 tons per day, but with a building so arranged as to admit of doubling the capacity of machinery.

The supply of beets is received from the Santa Maria and Arroyo Grande and adjacent smaller valleys. The total area of good beet land is estimated by the company as about 100,000 (?) acres.

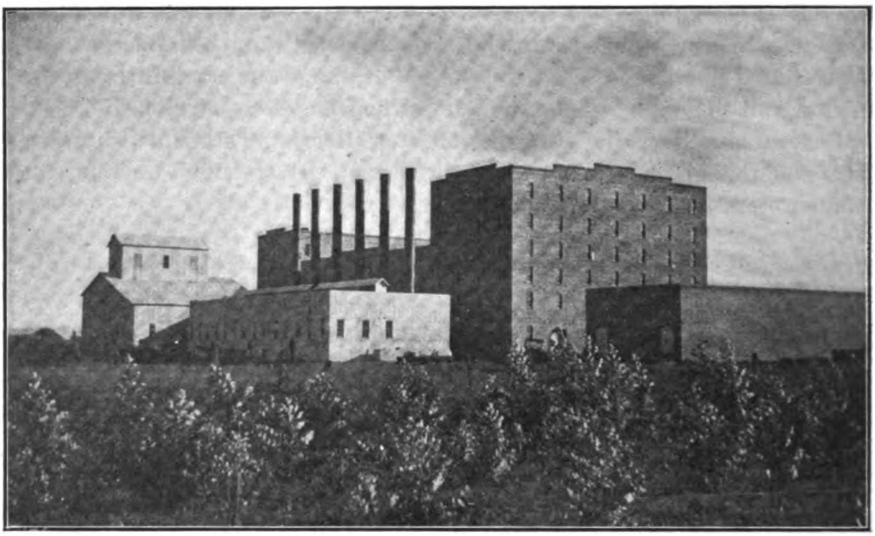

PLATE XIII. BETTERAVIA BEET-SUGAR FACTORY. CAPACITY, 500 TONS.

The Santa Maria Valley lies in the northern portion of Santa Barbara County, and together with Lompoc, Los Alamos, and Santa Ynez, all smaller valleys, comprise the main part of the acreage in the county. The southern part of the county is called the Santa Barbara Valley in general, and comprises Carpinteria, Montecito, Goleta, and Ellwood. It is from the northern part of the county that the beets are received. The soils of the valley have a reddish sandy and gravelly character from Fugler's Point westward to within four miles of the town of Santa Maria, where they change to a grayish character. Still westward toward the sugar factory they become more loamy in character, and it is upon these loam soils that the best results with beets have been secured.

This loam soil with proper moisture should be productive of all crops suitable to that climate, for it is well supplied with potash, phosphoric acid, and humus. Its lime content is somewhat low.

Abundance of water lies at a depth of from 40 to 75 feet, but can not be had as flowing artesian water. If irrigation is practiced it must be by pumping.

The valley of Arroyo Grande, in the southern part of San Luis Obispo County, is noted among seedsmen of the United States as being capable of producing seeds of maximum value. The soil for the most part is a heavy dark clay, gradually becoming more sandy until it finally ends in the sandhills of the coast. The water capacity of the land is very great, reaching as high as 77 per cent by weight. The soil is very rich in all the elements of plant food.

The climatic conditions in these regions do not differ materially from those described for other sections of southern California, except perhaps having a somewhat greater rainfall than those in the extreme south, which, taken together with the high moisture-holding power of the soil, particularly in the Arroyo Grande Valley, is particularly favorable.

With the other factories in the southern area this factory suffered much from the drought years of 1899 and 1900. While 6,500 acres of beets were planted the first year and the early part of the season looked very favorable, later the conditions became such that but 3,500 acres were harvested, which gave but 16,000 tons of beets, and the factory ran but 58 days. The season of 1900 gave correspondingly low returns, but in 1901 conditions were more nearly normal, and from 3,461 acres were produced 35,898 tons of beets, or 10.36 tons per acre, with a sugar content of 15 per cent and a purity of 80, giving the factory a run of 95 days. A tabulated statement of the factory operations is shown below:

TABLE XII.

BETTERAVIA FIELD AND FACTORY STATISTICS, 1899–1902.

	1899.	1900.	1901.	1902.
Acres of beets harvested	3,638	2,933	3,461	3,192
Tons of beets produced	16,664	12,419	35,898	37,218
Average yield per acre, tons	4.58	4.23	10.36	11.70
Total amount paid farmers for beets	$71,655	$49,676	$165,131	....
Average per ton	$4 30	$4 00	$4 60	....
Sugar in beets, per cent	15.7	17.7	14.9	15.7
Purity coefficient	77.0	81.0	79.8	78.6
*Crude sugar per acre, lbs.	1,438	1,497	3,087	3,680
*Refined sugar per acre, lbs.	1,150	1,198	2,470	2,944
*Crude sugar per ton of beets, lbs.	314	354	298	314
*Refined sugar per ton of beets, lbs.	251	283	236	251
Campaign began	Sept. 20	Sept. 10	Sept. 3	July 21
Campaign closed	Dec. 6	Nov. 10	Dec. 19	Nov. 4
Length of campaign, days	77	61	106	106
Average returns per acre	$19 69	$16 92	$47 66	....

*Estimated by the writer.

At present the company itself grows about one half of its supply of beets on owned or rented land. Land for beet-growing rents for from $6 to $8 cash, or from one fifth to one fourth the crop, and ranges in price from $75 to $150 per acre.

It would hardly be just to the region to make any comparison of returns per acre, for two out of the three years during which the factory has operated the climatic conditions have been worse than any previous ones in the history of the State. With anything like a favorable year the locality is sure to give both excellent yields and good quality of beets, which was well illustrated in 1901 and is again evidenced this season, the crop being estimated at about 40,000 tons from about 4,000 acres.

GENERAL CONSIDERATION OF THE SUGAR INDUSTRY.

Advantages Accruing from Beet Culture.—Collecting some of the more important items for a more comprehensive view of the status of the industry in the State in general, particularly upon the agricultural side since 1888, we find that on a total of 326,000 acres there has been an average production of 9.8 tons of beets per acre annually, giving an average return of over $44 per acre, or a net profit of about $14 per acre, which certainly compares favorably with other crops grown in the State. A like number of acres devoted to wheat and most other agricultural crops for the same period would have produced a decidedly less return per acre, if average price and yield per acre be taken as the basis.* The figures above stated can not be taken as the entire value, for there should be included the better condition in which the land is left for the growth of other crops, provided the beet crop is properly handled by returning the tops to the field either by plowing-under or feeding them and returning the manure to the field. This, of course, is difficult to express in money value. It is pertinent, however, to say that in Europe the increased production of cereals resulting from beet culture has been shown to be very material, as will appear below.

The ten-year average crop from a 625-acre farm growing cereals was 5,736 bushels of grain before beet culture was introduced. After beet culture was introduced 125 acres were planted each year with sugar beets; the average crop of grain from the remaining 500 acres was 5,730 bushels yearly, being a clear gain of the product from 125 acres. Thirty-five other farms showed the following increase after the introduction of beet culture, in a ten-year average:

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* As against the above figure it is notable that the gross return from all cultivable land in this country in 1901 was less than $10 per acre, and for cereals was but a little over $8 per acre; while crops of beets yielding as high as $25 to $30 per acre were not at all uncommon.

TABLE XIII.

Showing Increase in Various Crops Due to Introduction of Beet Culture.

	Average Pounds per Acre.		
	Before.	After.	Increase.
Wheat	1,848	2,128	280
Rye	1,456	1,672	116
Barley	1,672	2,094	322
Oats	1,355	1,918	563
Peas	985	1,834	949
Potatoes	11,716	13,569	1,853

It is said that there has been an increase of about 21 per cent in all crops in Germany and Austria-Hungary in consequence of sugar-beet culture.

There would seem to be four very valid reasons why farmers should turn more attention to the beet crop:

1. It is a cash crop, with a price practically fixed.
2. It is one of the surest crops a farmer can grow, if given the requisite care.
3. There is more money in it than in most other crops, if it be grown under proper conditions.
4. It increases the production of other crops, because of the deeper cultivation.

The business has often been given a setback in new regions by the too ardent claims of promoters, who have either encouraged the growing of beets upon soils not at all adapted to the crop, or have encouraged farmers, entirely ignorant of its exacting requirements, to contract for a much larger acreage than they could possibly handle, the inevitable result being failure and disappointment. These failures do not at all reflect upon the industry as such, but are causes of serious loss to both factory and farmer. It is far better for a factory to have a smaller acreage grown, and have it grown successfully, than to have a large one coupled with a partial failure. This matter is particularly pertinent in localities where the industry is being inaugurated, and should receive the most careful attention of managers of new factories. A factory has a much brighter prospect for ultimate success if it secures few acres distributed among a large number of small farmers than with a larger number of acres grown by a few contractors. This is one of the potent reasons of the success in Utah. The industry is notably one for the small farmer, who should be encouraged to turn attention to the crop as generally a remunerative one; but there is no royal road to riches, even through the sweetness of the sugar beet.

A Review of the 1901 Campaign.—The season of 1901 may be considered as having been generally favorable to the industry not only in California but elsewhere as well. Below will be found a table showing

TABLE XIV.

COMPARATIVE BEET-SUGAR STATISTICS FROM SEVERAL STATES.

STATE.	Acres of Beets.	Tons of Beets Worked.	Total Sugar Produced.	Total Cost of Beets.	Average Yield per acre. Tons.	Average Cost per Ton.	Quality.		Sugar per Acre, lbs...	Sugar per Ton, lbs. ..	Average Return per Acre.......	Tons Beets to One Ton Sugar......	Character of Season..
							Average Sugar.	Average Purity.					
California	57,979	643,454	143,947,800	$2,895,545	11.09	$4 50	15.9	80.8	2,482	224	$49 94	8.9	Fair.
Michigan	59,949	507,865	106,267,500	2,285,392	8.47	4 49	14.2	82.8	1,772	209	38 12	9.5	Fair.
Colorado	19,669	192,629	47,411,600	866,830	9.79	4 50	17.1	83.0	2,410	246	44 06	8.1	Good.
Utah	12,506	143,266	30,710,000	644,698	11.45	4 50	14.0	82.9	2,455	214	51 55	9.3	Fair.
Nebraska	7,917	70,110	14,912,300	315,496	8.86	4 50	13.1	79.3	1,883	212	30 98	9.4	Fair.
Washington	1,500	10,500	2,200,000	47,250	7.00	4 50	17.0	85.0	1,467	209	31 50	9.5	Fair.
Oregon	2,300	12,719	3,066,000	57,236	5.53	4 50	16.0	85.0	1,333	241	20 53	8.3	Fair.
New York	5,993	46,600	9,337,983	209,700	7.77	4 50	13.7	83.4	1,558	200	34 99	9.9	Fair.
Ohio	1,800	12,300	2,492,000	55,350	6.83	4 49	12.7	76.2	1,384	202	30 75	9.8	Poor.
Wisconsin	2,470	18,245	3,466,550	82,102	7.39	4 50	14.8	82.3	1,403	190	33 23	10.5	Poor.
Minnesota	3,200	28,000	5,400,000	126,000	8.75	4 50	14.0	81.0	1,687	193	39 37	10.3	Good.

TABLE XV.

FACTORY OPERATING-STATISTICS, BY STATES—CAMPAIGN OF 1901.

STATE.	Beets Worked.		Fuel Used.				Limestone.		Labor, Factory.	Cost per Ton.				
			Coal.		Oil.									
	Tons.	Cost.	Tons.	Cost.	Barrels.	Cost.	Tons.	Cost.		Beets.	Labor.	Coal.	Oil.	Lime-stone.
California	643,454	$2,895,545	7,400	$22,200	669,509	$234,327	76,640	$153,280	$587,378	$4 50	$0 91.2	$0 88.4	$0 37.9	$0 23.9
Michigan	507,865	2,285,392	103,250	306,750	....	....	44,971	84,942	553,648	4 49	1 09.0	50.4	....	17.7
Colorado	192,629	866,830	43,912	128,736	....	....	15,115	30,230	201,404	4 50	1 04.5	66.3	....	16.5
Utah	143,266	644,698	21,002	63,006	....	....	7,882	15,754	93,372	4 50	65.1	1 47.0	....	10.8
Nebraska	70,110	315,496	15,006	45,018	....	....	8,878	17,756	73,844	4 50	1 05.3	43.3	....	25.3
Washington	10,500	47,250	1,375	4,125	....	....	850	1,700	12,150	4 50	1 15.7	39.3	....	16.2
Oregon	12,719	57,236	....	....	....	....	780	1,560	16,000	4 50	1 25.8	....	....	12.3
New York	46,600	209,700	7,933	23,799	....	....	2,894	5,788	34,790	4 50	70.4	51.1	....	12.4
Ohio	12,300	55,350	3,300	9,900	....	....	1,035	2,070	20,000	4 50	1 62.6	59.2	....	16.8
Wisconsin	18,245	82,102	3,101	9,303	....	....	1,277	2,554	38,016	4 50	2 08.4	51.0	....	14.0
Minnesota	28,000	126,000	5,950	17,850	....	....	3,000	6,000	36,000	4 50	1 28.6	63.8	....	21.4

collective results for the California factories for that year and also similar results for factories in other States. It will be noted that the conditions are generally reported as fair, and especially is this true for the leading sugar-producing States—California, Michigan, Colorado, and Utah. Although the results are reduced to average per ton or acre, as the case may be, yet it is hardly just to compare the States having but a limited acreage and but a single factory with those where several factories are located. For the sake of complete records, however, the figures from all the States are included.

It will be noted that Michigan cultivated a larger number of acres than California, but the total tons of beets produced was less by 35,000. In the average yield per acre California with 11.09 tons is surpassed only by Utah with 11.45 tons, and if we exclude the two localities in California in which the conditions are reported as *poor*, it would give her an average of 12.6 tons per acre, or an average of one ton per acre more than produced in any other State, which may be taken as a fair index of her producing power *when moisture conditions are at all favorable.*

To maintain her high producing power attention must be given to the matter of irrigation; it is the only way in which the fickleness of climate can be overcome. Given climate, and the farmer is largely independent of the soil question when rational methods of culture are observed.

It is interesting to note that the average price per ton is the same in all States, $4.50. But in this connection it should also be noted that the Eastern factories are paying more for their raw material, when the quality is considered; in other words, it is costing them more per ton of sugar.

When the season's returns per acre to the farmer be considered, Utah with $51.55, again is the only State which exceeds California with $49.94, but it has probably cost her that much more to irrigate her land, this extra cost, however, being well spent in order to make sure of a crop, a condition which is devoutly to be wished for in California. Given a favorable season, and there is probably not a State that can surpass California (even if any can equal her) in the number of tons of high-grade beets that can be produced per acre.

The Cost of Manufacture.—Turning attention to a phase of the industry which appeals to the business man, we find that 643,454 tons of beets produced 71,974 tons of sugar, or 8.9 tons of beets to one ton of sugar. The cost of producing this sugar for each factory can not be exactly stated, nor would it be just to the individual factory to do so. Attention should be called, however, to some figures along this line that recently appeared in the report of Mr. C. F. Saylor on "The Progress of the Beet-Sugar Industry in the United States for 1901," page 36, under the head "Cost of working one ton of beets," from which very erroneous conclusions might be drawn. The writer there states only the cost of labor (factory), fuel, and limestone, mentioning no other items which enter into the cost of working a ton of beets, and leading one to infer that from these items we might arrive at a close estimate of the cost of making one ton of sugar. A practical factory man, however, knows that this does not include many items which always enter into the cost of sugar production. Any just estimate must include many other things which involve a heavy annual outlay and must be charged to the season's run. Among these are sacks, coke, filter cloth, knives, oil, soda, tallow, acid, and repairs, all of which would easily amount to 50 cents per ton of beets.

Limiting ourselves to California conditions and basing our figures now *simply on the handling of the beets in the mill*, the statement of *factory expenses* would stand about as follows:

	Per Ton of Beets.
Labor	$0.912
Fuel	.379
Limestone	.239
Miscellaneous supplies	.500
	$2.030
Cost of beets	4.500
	$6.530

While the above expresses in a very general way the factory expenses, yet, as a matter of fact, there are still other items which must be included, for, outside of a company's field operation, the cost of manufacture must actually stand a certain allowance for depreciation and changes, which is usually considered to be about 7 per cent on the original cost, or $1.089 per ton of beets; there must also be added at least 80 cents per ton of beets for interest, taxes, and insurance, and approximately 5 cents per ton for selling expense. This makes a total of $8.469 per ton of beets, or according to the figures for the tons of beets per ton of sugar, $74.37 per ton of refined sugar.

In connection with the above some researches of Mr. Paul Doerstling, a well-known German authority and contributor to American and European sugar journals, into the cost of sugar production in various countries, is interesting. Mr. Doerstling's compilation shows as follows:

BEET SUGAR.

	Tons Beets per Acre.	Tons Sugar per Acre.	Cost of Sugar per Ton.
Germany	12.5	1.2	$49 00
Austria	9.3	1.1	47 00
France	10.9	1.2	58 00
Russia	7.2	0.8	60 00
General average	10.0	1.07	$53 50

CANE SUGAR.

	Tons Cane per Acre.	Tons Sugar per Acre.	Cost of Sugar per Ton.
Spain	17	0.9	$55 00
Japan	15.5	1.3	78 00
Java	32	3.0	38 00
Straits Settlement	20	1.6	41 00
Egypt	19	1.9	45 00
Reunion	21	1.9	69 00
Louisiana	22	1.9	75 00
Cuba	24	1.8	40 00
East Indies	....	1.0	36 00
Hawaii	22	2.8	39 00
Argentina	13	1.0	62 00
British West Indies	....	1.7	47 00
Queensland	...	1.7	29 00
Porto Rico	20	2.0	28 00
General average	20	1.75	$62 00

Mr. Doerstling's figures refer to the manufacture of *raw* sugar, and to make them comparable with those for California, must have the cost of refining added.

The selling price of this sugar in 1901 did not vary much from $80 per ton, thus giving a profit of only about $5.63 per ton, or a total profit of but $405,213, or about 4 per cent on the investment in the factories in the State, which, under fair years of production, may be considered a minimum, as sugar has ruled at its lowest figure during this period. With sugar at 5 cents it would mean about 18 per cent, which, when all attendant risks are considered, can not be considered excessive. It should be stated, however, that so favorable a season as 1901, and a high average price for sugar, do not often occur together, and that even in favorable seasons this higher profit should be cut in two as representing fair average returns to the factory.

It should be distinctly understood that in this estimate there is drawn a sharp distinction between the purely manufacturing and the agricultural operations which are often conducted by the companies themselves and enter into any final profit or loss to the company. The growing of sugar beets is distinctly a business for the small farmer, and it is very questionable whether any company can produce beets as cheaply, even under the most favorable conditions, as can the individual grower with a smaller acreage, and consequent closer supervision of work. With the least laxity in supervision it becomes a very easy matter for a company to lose in the field all that is really made in the factory, and the manufacture of sugar forced to bear the burden of field losses. The economic *production* of sugar in the field is a far more intricate matter than the *extraction* of it in the factory, and demands an entirely separate consideration.

Often it is not considered that the profit from the manufacture of sugar may be materially influenced after the crop is grown, and especially so in case a flat price is paid for the beets, which practice much prevails in this State. Warm, moist weather during harvest time—a condition which not infrequently obtains in the northern part of this State—invariably causes a serious loss in sugar. A case in point is stated by one of the factories:

AVERAGE PERCENTAGE OF SUGAR IN BEET.

1894—September	13.6
October	12.8
November	10.8
December	10.5

While in the same months the year previous the figures were 13.4, 14.4, 14.7, 14.9.

When all things are considered, it must be admitted that when a flat price of $4.50 per ton is offered for beets the factory is offering as large a price as it can afford with sugar as fluctuating as it has been in recent years, and with political conditions as unsettled in the sugar world as they are at the present time.

A careful survey of the conditions as they exist to-day can lead to but one conclusion, viz., that the industry is generally in a healthy status from both the manufacturing and the agricultural standpoints, and that the only thing which can possibly prevent California from ultimately maintaining her position as the leading beet-sugar-producing State is the fickleness of her climate with respect to moisture, or unfavorable Congressional action. With a more extensive introduction of irrigation into her agricultural and horticultural practice this single drawback will disappear, and we may reasonably expect to see a great expansion of the industry.

The capital necessary for building factories is abundant. There are perhaps now in this country several million dollars awaiting investment in beet-sugar factories just as soon as investors can be assured of the coöperation of farmers in suitable localities.

Not California alone, but the entire country is interested in the permanent establishment of the beet-sugar industry in those districts which are best adapted for it, and under those conditions which will best conduce to the upbuilding of a prosperous trade.

What California Can Do in Beet Sugar.—It is not the purpose to discuss the individual localities in California which may be suitable for the location of factories. Numerous localities, however, are known to possess the requirements for success in the industry. In a very general way we may say, quoting Professor Hilgard in "Pacific Rural Press," December, 1897, that "the total valley areas of this State exceed 12,000,000 acres. Estimating the sugar product per acre at the reasonable rate of

1¾ tons of sugar per acre, it would require only 1,125,000 acres, or less than one tenth of the entire valley area, to produce the 2,000,000 tons of sugar estimated to be the present annual consumption of the United States. But with the successful use of irrigation, a considerably larger proportion than this consists of lands intrinsically suitable for sugar-beet culture, so as to admit also of a proper rotation of crops. California alone, then, could readily supply the entire present and prospective sugar consumption of the United States, and still leave ample room for orchards and vineyards and the production of the home supply of breadstuffs. It is perhaps not probable or desirable that this one branch of production should be pushed to this extent; but it would be strange indeed if, with such extraordinary climatic advantages, it failed to attain a more prominent and lucrative position among the agricultural industries of California than at the present time. Climatic considerations as well as soil quality point especially to the valleys of the coast region, from Mendocino to Los Angeles, and the Sacramento and lower San Joaquin valleys, as adapted to it. Excessive heat and dryness in summer are unfavorable for the preservation of that crispness which is deemed essential in a first-class sugar beet. All the essential conditions of success in its cultivation seem to be combined in a large portion of the 'Alameda plains' and other level or gently sloping lands of the Bay coast region, and Sacramento and Salinas valleys, where the lighter sediment soils prevail, and where at present cereal culture, or that of fruit, constitutes almost the only alternative. Southern California, also, has given excellent results as regards both quality and quantity of the sugar-beet crop, in the Chino and Santa Ana regions; and Ventura and San Luis Obispo can with certainty count on a similar outcome. As to the San Joaquin Valley, the sugar beet can probably be grown successfully, without irrigation, on suitable lands as far south as Merced"; with the development of irrigation systems the area could be considerably extended.

The promise of permanence given by this valuable industry makes it desirable that everything possible should be done to safeguard and cherish it as one of the chief resources of California.

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1896. Report of the Viticultural Work during the seasons 1887-93, with data regarding the Vintages of 1894-95.

1897. Resistant Vines, their Selection, Adaptation, and Grafting. Appendix to Viticultural Report for 1896.

1898. Partial Report of Work of Agricultural Experiment Stations for the years 1895-96 and 1896-97.

1900. Report of the Agricultural Experiment Stations of the University of California for the year 1897-98.

BULLETINS.

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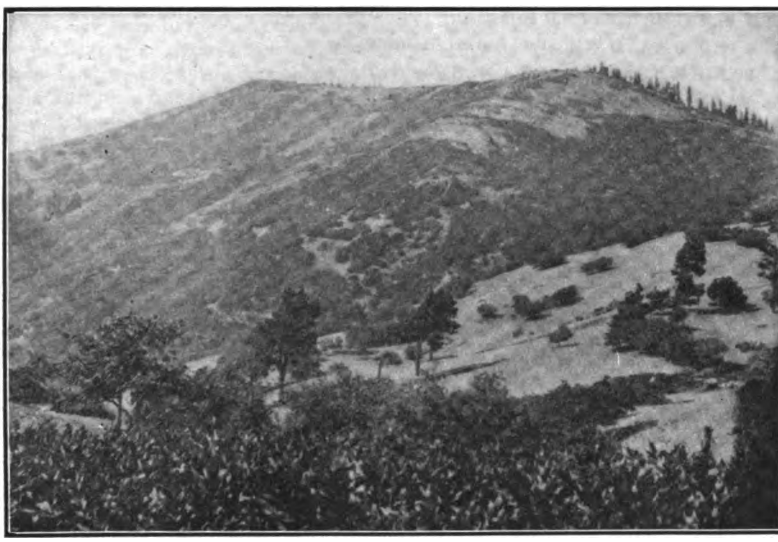
UNIVERSITY OF CALIFORNIA PUBLICATIONS.

COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

THE VALUE OF OAK LEAVES FOR FORAGE.

By W. W. MACKIE.



SIGNAL PEAK, IN EASTERN MENDOCINO COUNTY.

Slopes covered with low-growing *Quercus garryana*, and open places where covering has been killed by sheep. In the foreground is False Hellebore (*Veratrum*), an indication of moist ground.

BULLETIN No. 150.

(Berkeley, April, 1903.)

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1903.

BENJAMIN IDE WHEELER, Ph.D., LL.D., *President of the University.*

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E. J. WICKSON, M.A., *Horticulturist, and Superintendent of Central Station Grounds.*
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THE VALUE OF OAK LEAVES FOR FORAGE.

The exploration in the course of which the data and samples forming the basis of this bulletin were gathered, was originated by the Bureau of Forestry of the Department of Agriculture, with a view to a study of the forest resources of the region in question. At my request, Mr. Mackie paid some attention to the pasture conditions existing there, to serve as a complement to the previous exploration of Mr. Joseph Burtt Davy in northwestern California, the results of which were published in Bulletin No. 12, of the Bureau of Plant Industry of the Department. Mr. Mackie found somewhat unexpectedly that a large part of the actual nourishment of stock in the region was obtained by browsing on the various oaks, and on his return I suggested to him, as an interesting subject for his graduating thesis, an examination of the chemical composition and nutritive value of the several kinds of oak leaves usually eaten by stock. The results of this work, carried out in the Station laboratory, together with the general information obtained regarding the importance of browsing forage as against the rapidly deteriorating grass range, form the subject of this paper.

E. W. HILGARD.

During the summer and fall of 1902, while experting a forest reserve in the northern Coast Ranges, the writer noticed with surprise and interest the eagerness with which leaves of certain oaks were eaten by live stock. Having this fact in mind, many observations were made in regard to the forage value of each species of oak occurring in the Coast Ranges. These observations, while confined more especially to the extent to which each species was eaten by stock, included also the range or distribution, altitude, and mode of occurrence.

Later in the year, in order to ascertain, if possible, whether these observations indicated fully the real value and significance of these oaks for forage, a chemical analysis was undertaken covering six species of oaks and one of poison oak. Only those species were chosen which occur on hills, ridges, and mountains where tillage is impossible; and the object kept continually in mind was the forage value of the leaves of the different species.

It is the purpose of this paper to give in full the results of both observation and analysis, and to discuss the harmony or lack of harmony between the two.

The ranges covered by the investigation are those situated in Lake County, in eastern Mendocino north of Ukiah to Humboldt County, in the western parts of Colusa and Glenn counties, and in southwestern

Tehama County. These northern Coast Ranges are broken up into many ridges, all running northwest and southeast. Between them are small, narrow, gravelly valleys, with very little cultivable soil. The mountains and slopes are composed of shales or loose soft rocks, often volcanic in formation. The soil formed by decomposition of these rocks on ridges is very shallow and poor—seldom as deep as four feet and commonly two or less. The decomposition of these shales is hastened by the growth of chaparral, herbs, and grasses, and on these poor, shallow, rocky soils the browsing oaks are found. In the sedimentary or alluvial, or even the colluvial soils washed from these mountains, none of the browsing oaks are found. These oaks, therefore, are good indicators of poor, shallow, and rocky soils.

This area is typical of all the northern Coast Ranges, and, in regard to oaks, may be taken also as a type of the southern Coast Ranges. Thus the browsing areas of the Coast Ranges alone cover about one third of the State. Adding to these those areas of the lower foothills of the Sierra Nevada, which are occupied in part by many of these same species of oaks, we have, as the entire region enriched in many places by browsing oaks, about one half the State area.

Of the six species of oaks chosen from this browsing area for investigation and here discussed, three are peculiar to California. The remaining three species (*Quercus garryana*, *Q. californica*, and *Q. chrysolepis*) range north into Oregon, as also does the Poison Oak, a species of sumach. Each of these oaks varies in range according to temperature. altitude, and humidity; and the value of each species as a "browse" increases almost directly with the altitude, except when modified by exposure to the direct rays of the sun. Beginning on the lower hills. the six species succeed one another upward in nearly distinct zones or ranges, as follows: Blue Oak (*Quercus douglasii*), Scrub Oak and Curl-leaf Scrub Oak (*Q. dumosa* and its variety, *bullata*), Cañon Live Oak (*Q. wislizeni*), Maul Oak (*Q. chrysolepis*), Black Oak (*Q. californica*), and White Mountain Oak (*Q. garryana*). In addition to these, the Poison Oak (*Rhus diversiloba*) is found commonly everywhere, on hills, slopes, and by streams.

In the following description we will attempt to characterize each individual species in the above order, as regards form, mode of occurrence, range, and the forage value as indicated by the stock feeding upon it.

BLUE OAK (*Quercus douglasii*).

The Blue or Rock Oak reaches, in favored localities, a height of 20 feet, but is commonly found as a small tree about 12 feet high, or as a shrub from 4 to 6 feet in height. It is oval or round in appearance, and is covered densely with dark bluish leaves. The leaves are obovate to oblong, with lobes commonly increasing in size toward the apex. In young trees and shrubs the leaves are inclined to become spinescent. The acorns, borne in shallow cups, are oval to ovate-acute, and are about 1 to 1½ inches long.

In altitude, this oak is limited to the low foothills and dry valleys where the soil is hard and rocky, and never ranges upward to the higher slopes and valleys. It is found most abundantly in the dry foothills of

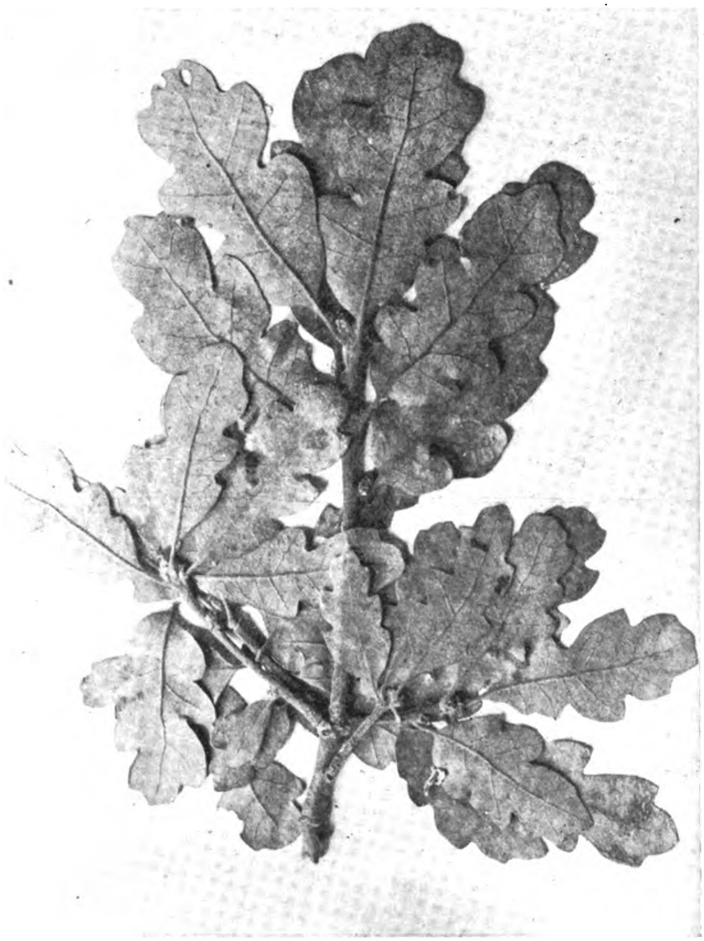

PLATE I. QUERCUS DOUGLASII. (BLUE OAK.)

the inner Coast Ranges, but extends from Mendocino County and the upper Sacramento Valley through the Coast Ranges and Sierra Nevada to Tejon Pass, in Kern County, from whence stunted individuals extend to the margin of the Mojave Desert. In the southern Coast Ranges it reaches its maximum height of fully 30 feet.

On account of the dryness of its leaf, only goats and sheep browse on the Blue Oak; but the acorn mast, which is plentiful and quite certain, is excellent feed for hogs, cattle, sheep, goats, and often for horses.

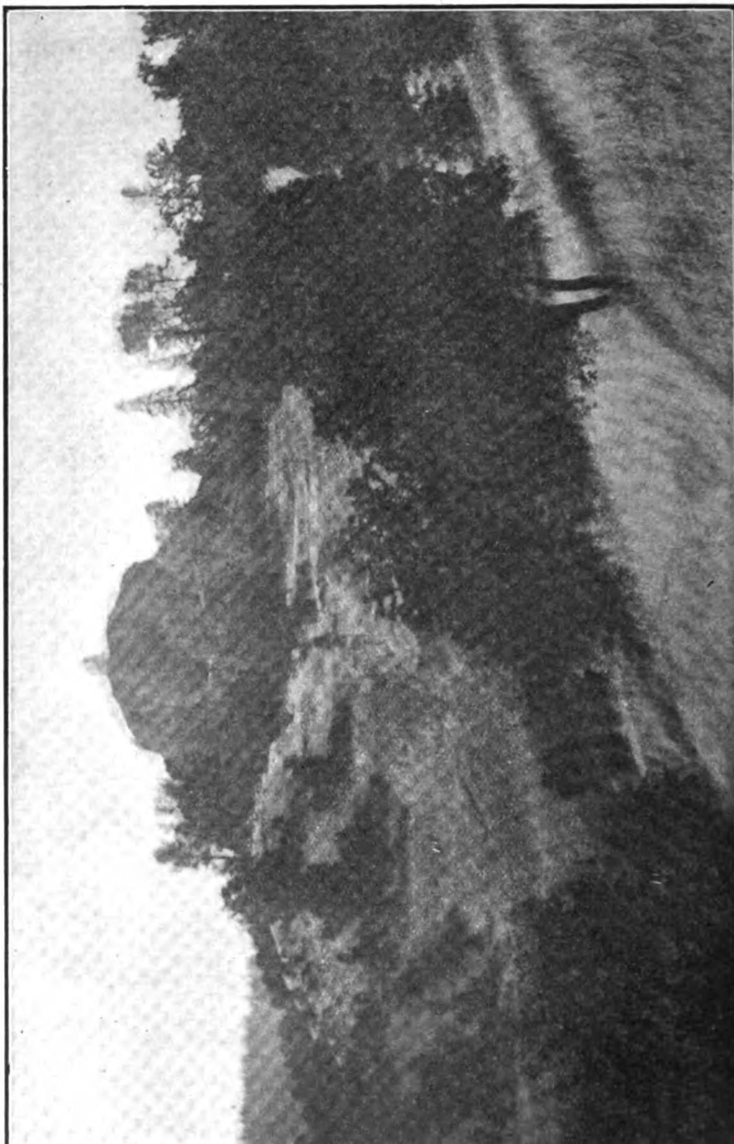

PLATE II. QUERCUS DOUGLASII. (BLUE OR ROCK OAK.)
In its natural range on Eel River, Lake County. Bloody Rock, where the last of the Chumiah Indians perished.

SCRUB OAK (*Quercus dumosa*).

This oak is a round-topped shrub 5 or 6 feet high, consisting of numerous closely tangled branches starting from near the ground. The twigs are usually tomentose, with leaves bunched at the ends. The leaves are oblong to obovate and entire on the older trees, but are often sinuate-toothed and spinescent in young shrubs. They are pale green in color and pubescent on the lower side. The acorns are oval and

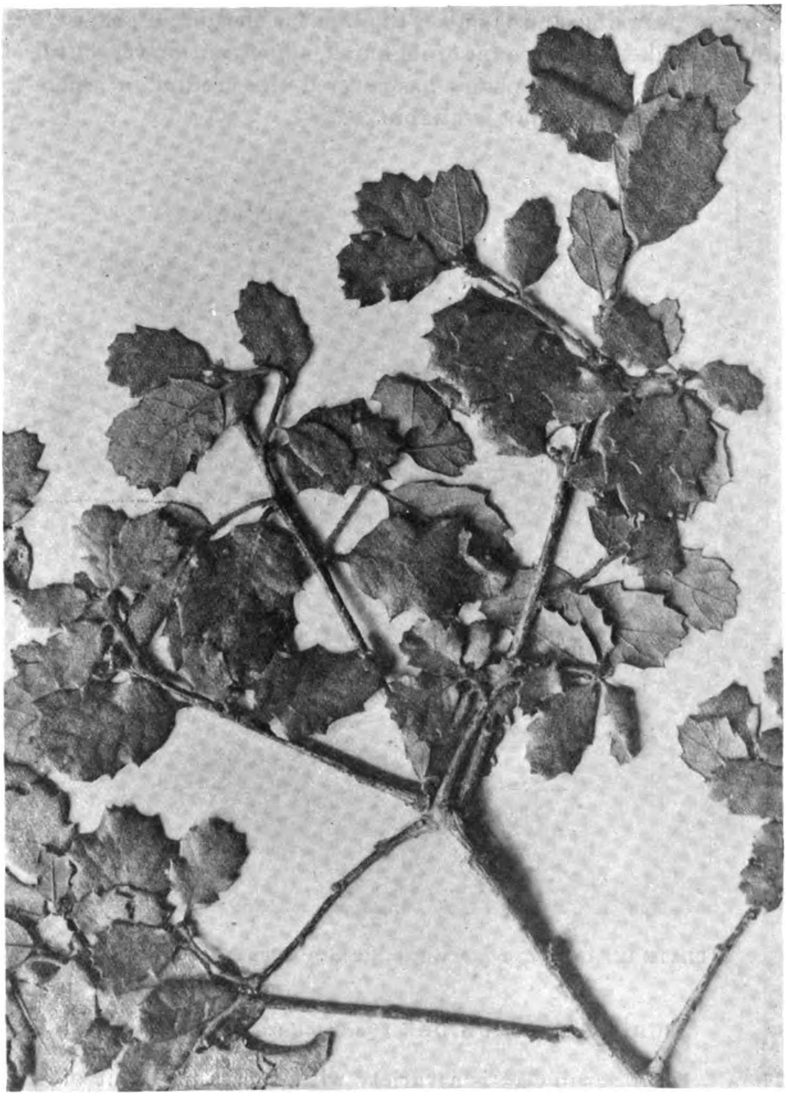

PLATE III. QUERCUS DUMOSA. (SCRUB OAK.)

pointed, from ½ to 1½ inches long, and are contained in shallow cups. The crop is light and very uncertain.

The Scrub Oak is commonly found associated with many other shrubs in the chaparral of the mountains and upper foothill slopes in dry localities. It ranges from Mendocino County southward through the Coast Ranges to Lower California, and is also found in the foothills of the Sierra Nevada.

This shrub, on account of its low habit of growth, is particularly adapted to browsing, and is one of the best for sheep and goats. Cattle, however, dislike it on account of its harsh, spinescent leaves, but feed on it during the winter when snow has covered the ground, or when from any cause other food is not available.

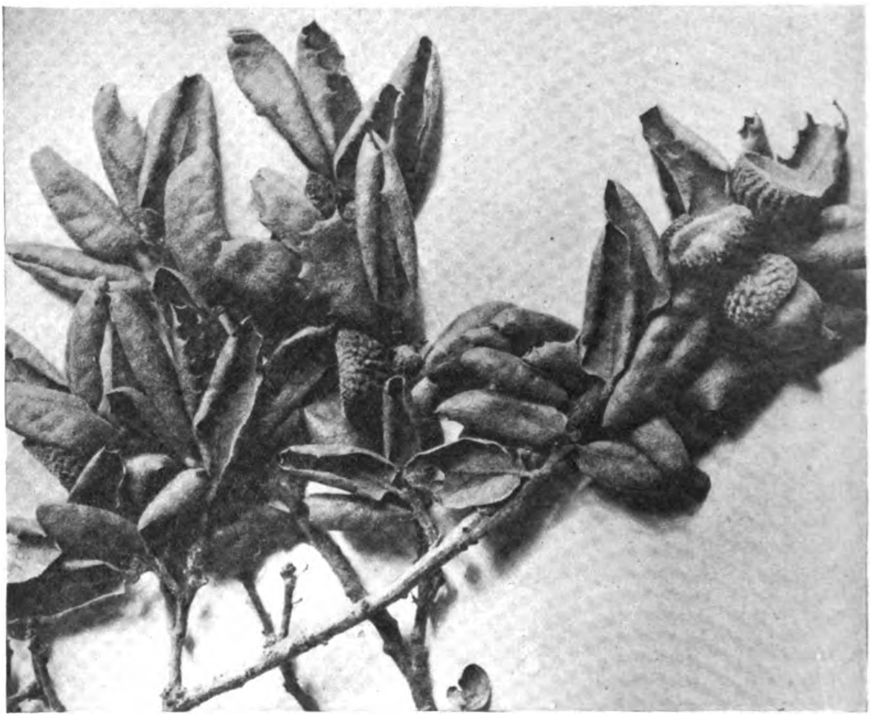

PLATE IV. QUERCUS DUMOSA, VAR. BULLATA. (CURL-LEAF SCRUB OAK.)

CURL-LEAF SCRUB OAK (*Quercus dumosa*, var. *bullata*).

The Curl-leaf Scrub Oak is a variety with the same habit of growth as the typical species. The leaves differ, however, in having the margins strongly revolute, thus presenting a curled appearance. The under side of the leaf is densely tomentose, and the whole leaf is thicker and rounder than that of the type. The acorns of the variety are similar in size and shape to those of the other, but are contained in even shallower cups.

This oak is seldom found south of San Francisco Bay, and reaches its greatest abundance north of Clear Lake, on the dry eastern slopes of the Coast Ranges bordering on the Sacramento Valley, and extending to Mount Shasta.

The forage value of the variety is apparently the same as that of the type of the species.

PLATE V. QUERCUS WISLIZENI. (CAÑON LIVE OAK.)

CAÑON LIVE OAK (*Quercus wislizeni*).

The Cañon Live Oak when found in the cañons is a tree usually 20 to 40 feet high, but when it passes into the chaparral it is never higher than 8 feet. Here it is an intricately branched shrub with a rounded top. The bark on old trees is rough and thick, but on shrubs it is smooth. The leaves are usually oblong-lanceolate, entire, serrate or dentate, and are lustrous and dark green in color. They are about 1½ inches long and ¾ of an inch wide. The nuts ripen in the second season, and are long, sessile, slender oblong-oval, set in deep scaly cups. The mast is usually scanty.

The shrub is common in the chaparral with *Quercus dumosa*, and ranges with it in altitude. It is well distributed in the Coast Ranges from Mount Shasta to San Diego County, usually at quite a distance

PLATE VI. QUERCUS CHRYSOLEPIS. (MAUL OAK.)
Showing two distinct leaf forms.

from the sea. It also exists, but not commonly, from Mount Shasta through the lower foothills of the Sierra to Tejon Pass.

The leaves of this shrub are sought in preference to those of the Scrub Oak by sheep, goats, and cattle, and it is thus often found stripped of its leaves.

MAUL OAK (*Quercus chrysolepis*).

The Maul Oak (*Q. chrysolepis*), when found growing on well-watered and protected slopes, is a tree 40 to 60 feet in height, with large sweeping branches. On exposed slopes, however, and on the upper ridges and peaks, it becomes a gregarious shrub with *Q. garryana*. The leaves are oblong, acute or cuspidate, entire on old trees but spinose-dentate on young ones and on shoots. They are pale and glaucous above, with

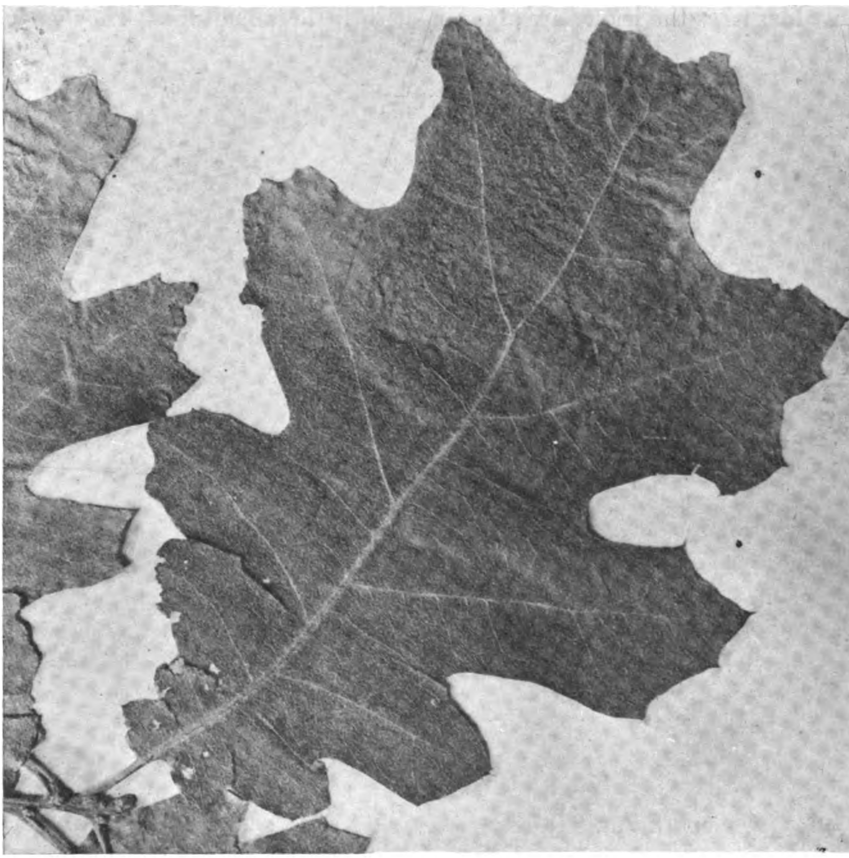

PLATE VII. QUERCUS CALIFORNICA. (BLACK OAK.)

golden tomentum below. The acorn is usually solitary, ovate or oval, ½ to 2 inches long, and borne in a shallow cup. The crop of mast is uncertain and is often ruined by the larvæ of moths.

The range of this oak extends from southern Oregon through the Coast Ranges and Sierra Nevada, and on through the San Bernardino Mountains to Lower California. It often reaches an elevation of 9,000 feet.

Maul Oak is used as a "browse" by sheep and goats, and sparingly by cattle.

BLACK OAK (*Quercus californica*).

The Black Oak is a tree 18 to 30 feet high, usually with several large erect branches. It is generally found near coniferous trees, and apparently occupying the same belt. Young trees often occur in dense growth, and, when in this condition or when overshadowed by other trees, grow slowly, thus enabling stock to browse on them. The leaves of young trees are covered with a dense gray tomentum below, and are pubescent above. On older trees the leaves are glabrous with little tomentum. They vary

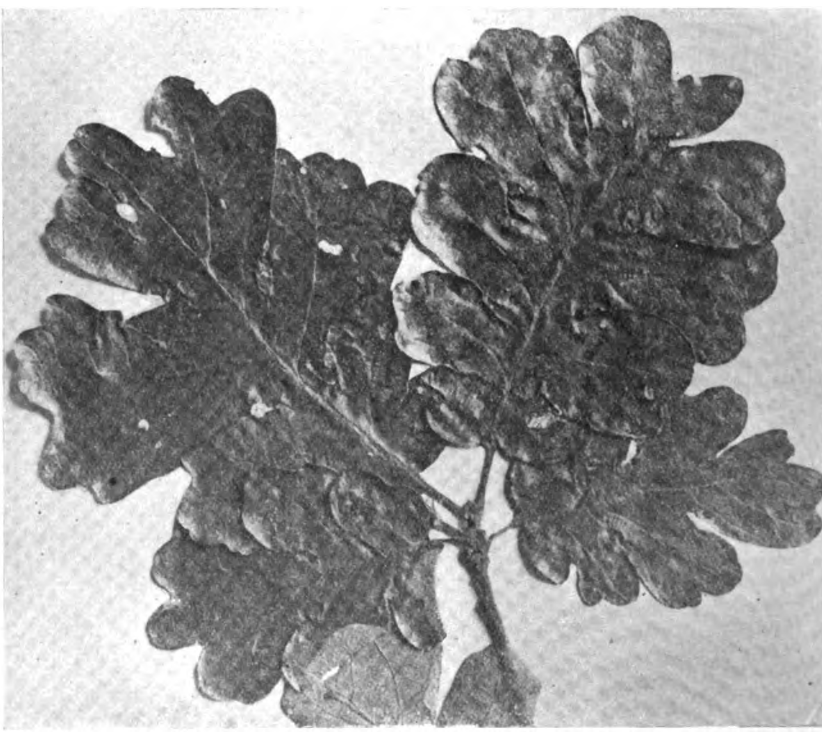

PLATE VIII. QUERCUS GARRYANA. (MOUNTAIN WHITE OAK.)

from oblong to broadly ovate in outline, and each is parted into about seven broad lobes. The nut is broadly ovate, one inch in length, and ripens in the second season. The crop is scanty and unreliable.

The range of the Black Oak extends from the Mackenzie River in Oregon through the Coast Ranges and Sierra, and through the San Bernardino Mountains to Lower California. This oak often reaches elevations of 7,000 to 8,000 feet. It is scarce near the coast.

The flexible texture of the leaves of this oak allows it to be easily eaten by cattle and horses as well as by sheep and goats.

WHITE MOUNTAIN OAK (*Quercus garryana*).

Two forms of this species, differing only in range and height of individuals, may be distinguished. The typical form is a tree from 30 to 70

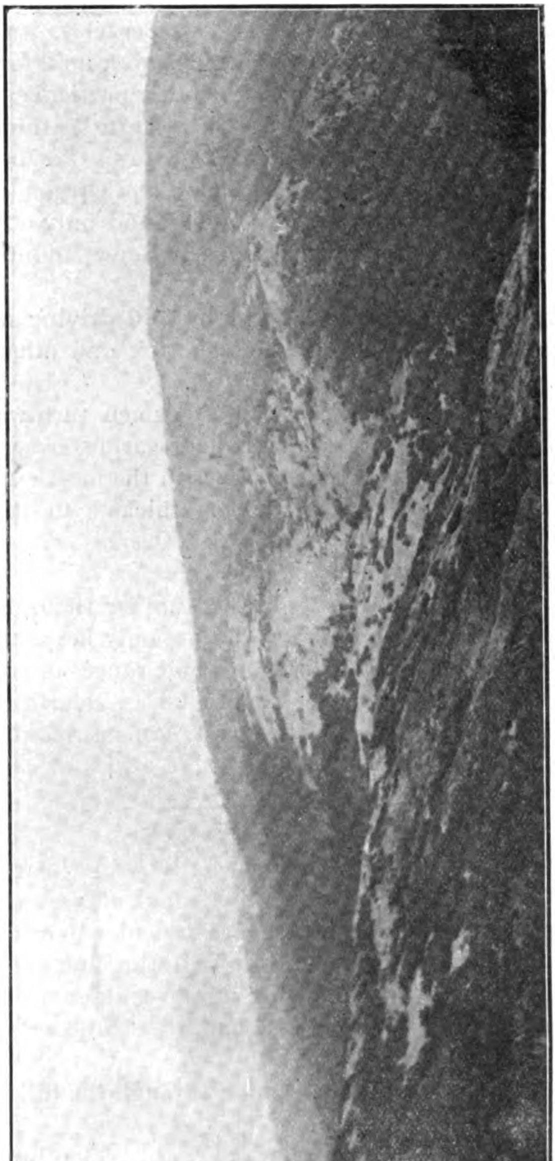

PLATE IX. SANHEDRIN MOUNTAIN, IN WESTERN MENDOCINO COUNTY.
Showing *Quercus garryana* pastures and bare places and erosion, the result of trampling and over-pasturing with sheep.

feet in height, with erect rigid branches. Its leaves are oblong to obovate, 4 to 6 inches long, with coarse lobes. The acorns are sessile or shortly peduncled, oval to slightly obovate, about 1 to 1¼ inches in length, contained in a shallow cup.

It ranges from Vancouver Island southwestward through western Washington, Oregon, and the Coast Ranges of California, to Santa Cruz. It is the only oak used for lumber on the Pacific Coast, and furnishes the oak lumber for the furniture factories of West Berkeley.

The other form of this species is a mere shrub from 2 to 6 feet high, but identical with the larger form in every other particular.

Its range begins in an exposed portion of western Washington, where apparently it is stunted by the severe sea-breezes. Passing along the western slopes of the Cascades in Washington and Oregon, its elevation continually increases until in California it is found only on the highest ridges and peaks. Its southernmost range is Snow Mountain in Lake County.

The entire range of this oak is swept by cold driving north winds, which apparently serve to keep the temperature and other conditions uniform throughout.

It is to this form of *Q. garryana* that stockmen turn when seeking "browse" in their mountain pasture. It is gregarious over hundreds of acres on the ridges, peaks, and higher slopes in the most exposed places of the northern Coast Ranges. It forms thickets to the exclusion of everything else except the Maul Oak (*Quercus chrysolepis*), and occasionally Wild Cherry (*Cerasus demissa*).

This species, almost unaided, supplies pasture for thousands of sheep and goats as well as cattle and horses, and not only keeps them up, but actually fattens them. The stock keep whole ranges of it eaten down often to within less than two feet of the ground. Aside from the value of the leaves, the acorn, which is quite sweet, forms a rich diet for stock. The mast is usually sure and abundant.

POISON OAK (*Rhus diversiloba*).

The Poison Oak (*Rhus diversiloba*) is usually a small shrub from 2 to 5 feet high, but occasionally it ascends the trunks of trees as a vine, to a height of 15 or 20 feet. The leaflets are orbicular to ovate, glaucous, with distinct venation. They contain an irritating and poisonous volatile oil, which poisons many persons by simple contact or even by diffusion in the air. The fruit is pale, about three lines thick, and quite abundant.

Rhus diversiloba is everywhere common through the hilly portions of California.

On the ranges the leaves and berries are readily eaten by sheep, goats, and horses, but not by cattle, as far as could be ascertained by observation and numerous inquiries. Many of the bushes are stripped entirely of leaves long before they would naturally drop them.

VALUE OF CALIFORNIA OAKS FOR BROWSING PURPOSES.

In summing up the value of these California oaks, the common classification into "live," or evergreen, and deciduous will be made. The former class includes Scrub Oak and Curl-leaf Scrub Oak (*Quercus dumosa* and variety *bullata*), Cañon Live Oak (*Q. wislizeni*), and Maul

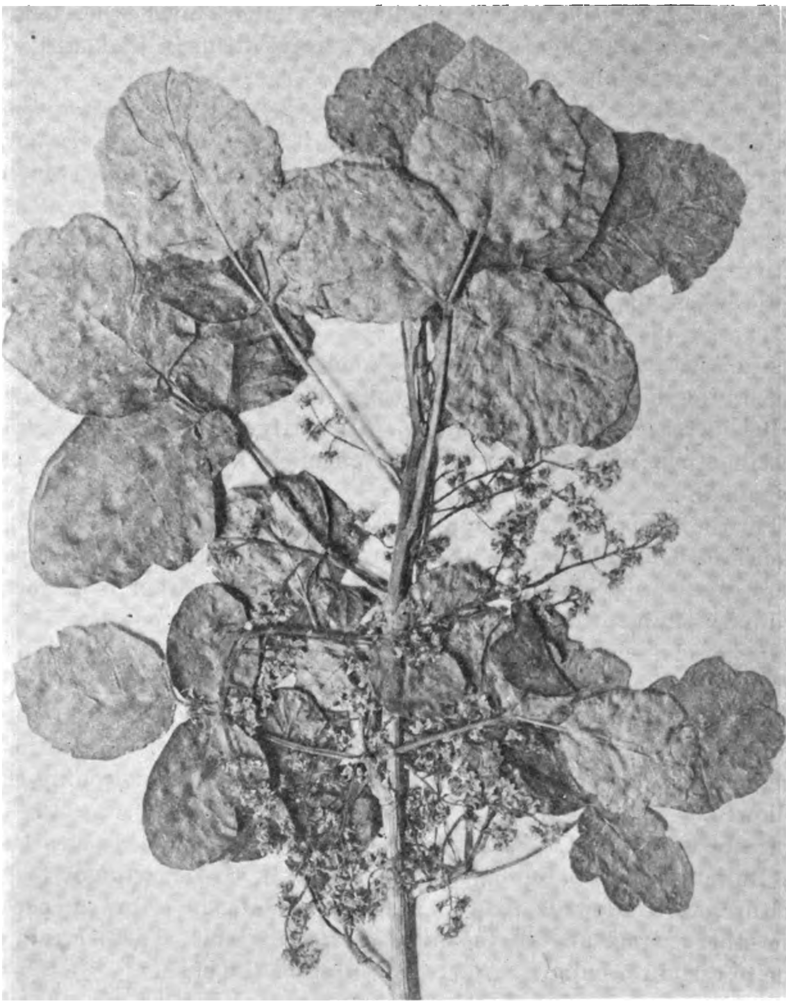

PLATE X. RHUS DIVERSILOBA. (POISON OAK.)

Oak (*Q. chrysolepis*). The deciduous oaks consist of Blue, or Rock Oak (*Q. douglasii*), Black Oak (*Q. californica*), and Mountain White Oak (*Q. garryana*). The Poison Oak (*Rhus diversiloba*) is also deciduous.

The live oaks, as seen in the previous descriptions, occupy the brush areas on the slopes and ridges, and, except for a few isolated specimens of *Quercus chrysolepis*, never grow within the timbered, or coniferous, belt. These live oaks, therefore, occupy a continuous belt of country which is free from snow except for occasional short periods. This belt, for this reason, is used as a winter range for holding-over stock when feed is scarce in the valleys and deep snows cover the mountains. Sheep and goats are kept in good condition on these live oaks, but cattle and horses do not eat them to any extent until other food can not be obtained. Then this "browse" keeps them in feed until other kinds are available.

The deciduous oaks, not taking into account the *Quercus douglasii*, which is of little forage value, are found in the timber belt or above it. The leaves of the deciduous oaks, in contrast to the harsh spinescent ones of the live oaks, are larger, lobed, and soft. This enables cattle and horses to eat them with ease, as is also true of sheep and goats. They actually fatten on the leaves of the Black Oak and White Mountain Oak of these upper ridges and peaks.

Nutritive Value of the Leaves.—From the observations just recorded concerning these several species of oaks, it would seem that the nutritive value increases with the altitude. To verify this, and to ascertain if possible their relative food values, a chemical analysis of each species was made.

For the purpose of this analysis the leaves were gathered during the month of September, when they were fully mature. Only those which were green and vigorous were taken. These were dried in a room of ordinary temperature, and were then ground to a fine powder.

It would seem that the irritating and poisonous oil of Poison Oak (*Rhus diversiloba*) is volatile at a comparatively low temperature. In gathering the specimen the writer was badly poisoned, even though gloves were worn; yet after drying at ordinary room temperature, and the leaves pressed into the mill with bare hands, no poisoning effects followed.

In the analyses of these oak leaves, the methods for foods, as set forth in Bulletin No. 46, Bureau of Chemistry, U. S. Department of Agriculture, were followed. In this work, however, some errors appeared in the ether extract and in the nitrogen-free extract. These errors were due to certain peculiarities of composition of the oaks.

In the determination of fat, or ether extract, quantities of chlorophyll, the green coloring matter in the leaves, remained in the extract. No quantitative method being known for the extraction of chlorophyll, this, together with the gums and resins which are contained within the leaves or on the tomentum and pubescence of the outside, increased the ether extract beyond its true percentage. After determining the nitrogen-free extract, which consists of sugar, starch, pentosans, etc., the percentage appeared inexplicably high. The only possible explanation seemed to be that the tannin content, which, by the method of difference, falls in this group, had not been accounted for. It was necessary, then, to make determinations of tannin.

In determining the tannin, the method of Günther was followed; that is, two grams of the substance to be analyzed was taken and the tannin extracted with hot water, in which it is easily soluble, until a dilution of 1 to 400 parts was obtained. This dilution is necessary in order that potassium permanganate may completely oxidize tannin in the presence of indigo-carmine. The oxidizing power of the indigo-carmine was determined by extracting all the tannin by means of animal charcoal and titrating with potassium permanganate. The difference between the two titrations was the tannin oxidized by the potassium permanganate.

With these exceptions in the ether extract and the nitrogen-free extract, the regular official method was followed; and the table below gives the results of the analyses of the different species of oak in an air-dry condition. As a means of exact comparison, these results were calculated first to a water-free basis, and finally, to an alfalfa hay basis. The analyses were all carried out in duplicate and the averages found as follows:

ANALYSES OF OAK LEAVES.

Species.	Water.	Ash.	Protein.	Fiber.	Tannin.	Nitr'gen Free Extract.	Ether Extract.
Samples Air Dry.							
	Per cent.	*Per cent*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Blue Oak	5.21	9.32	8.32	33.35	5.00	34.55	4.25
Scrub Oak	3.90	9.42	9.16	26.79	14.06	31.41	5.26
Cañon Live Oak	3.54	9.66	10.95	29.48	9.62	30.89	5.86
Maul Oak	6.53	9.62	8.32	30.35	10.16	31.52	3.50
Black Oak	5.10	9.35	8.15	19.22	10.62	40.50	7.06
Mountain White Oak	4.59	9.44	15.05	16.26	9.01	40.18	5.47
Poison Oak	5.39	8.66	6.85	25.13	6.42	41.05	6.50
Water-Free.							
Blue Oak	....	9.83	8.78	35.18	5.28	36.45	4.48
Scrub Oak	....	9.80	9.53	27.88	14.63	32.69	5.47
Cañon Live Oak	....	10.02	11.35	30.56	9.97	32.02	6.07
Maul Oak	....	10.29	8.90	32.47	10.89	33.73	3.74
Black Oak	....	9.85	8.59	20.25	11.19	42.68	7.44
Mountain White Oak	....	9.90	15.77	17.04	9.44	42.11	5.73
Poison Oak	....	9.15	7.24	26.56	6.79	43.39	6.87
Water on Alfalfa Basis.							
Blue Oak	10.95	8.75	7.83	31.32	4.70	32.46	3.99
Scrub Oak	10.95	8.72	8.48	24.83	13.03	29.11	4.87
Cañon Live Oak	10.95	8.92	10.11	27.21	8.88	28.52	5.41
Maul Oak	10.95	9.16	7.92	28.91	9.70	30.03	3.33
Black Oak	10.95	8.77	7.65	18.03	9.96	38.01	6.63
Mountain White Oak	10.95	8.82	14.04	15.18	8.41	37.50	5.10
Poison Oak	10.95	8.15	6.44	23.65	6.04	38.64	6.13
Alfalfa	10.95	6.43	17.60	22.63	....	39.31	3.08

In the discussion of the chemical analysis of these species, alfalfa hay is selected for comparison because alfalfa seems to be the best and commonest forage plant in California. A comparison with this plant, then, naturally sets forth the value of oak leaves for forage to better advantage than a comparison with any other stock food.

Ash Content.—In comparing the ash content of oak leaves and alfalfa, it is noted that the ash of oaks varies but little in various species. This variation is not more than four-tenths of one per cent, while the average ash for all the species is somewhat greater than 8.75 per cent. This percentage is 2¼ per cent greater than in alfalfa hay.

As all the mineral, and hence the bone-forming, materials of the plant are in the ash, oak leaves have thus a greater value for growing stock than has alfalfa.

Protein Content.—Proceeding to the protein, or muscle-forming content, greater variations are encountered. The comparison shows alfalfa to contain more than twice as much protein as any of the oaks, with the exception of two species, *Quercus wislizeni* and *Q. garryana*. The former averages 10.11 and the latter 14.04 per cent. *Quercus garryana*, therefore, approaches alfalfa closely. The other species, though falling far below alfalfa, are not poor in protein. The average is nearly 8 per cent, which is one-half of one per cent higher than oat hay—the best of cereal hays.

These analyses indicate that oak leaves are superior in muscle-forming ingredients to non-leguminous hay; that one species (*Quercus wislizeni*) is equal to bur-clover hay; and the best species (*Quercus garryana*) almost equal to alfalfa hay.

Crude Fiber.—In oak leaves the crude fiber is as variable as the protein, ranging from over 30 per cent in *Quercus douglasii* to 15 per cent in *Q. garryana*. With the exception of two of the deciduous oaks, *Quercus californica* and *Q. garryana*, the oak leaves are considerably higher in crude fiber than alfalfa. This crude fiber, or roughage, in oaks tends to produce a wide nutritive ration.

Ether Extract.—The fat, or more correctly speaking, the ether extract, is considerably higher than in alfalfa in all the species, and increases to twice as much in *Quercus wislizeni* and *Q. californica*. This ether extract does not represent pure fat, but includes the chlorophyll, waxes, and resins, which can not be separated from the true fat. These waxes and resins serve to protect the leaves from drying winds and inclement weather, and usually occur in the tomentum or pubescence which cover some leaves. In some cases, as in *Quercus californica*, the waxes and resins are distasteful to stock, thus decreasing their forage value.

Nitrogen-Free Extract.—In oaks the nitrogen-free extract, consisting of starch, sugars, pentosans, etc., does not equal alfalfa in any species, and in Scrub Oak falls as far below as 10 per cent. This fact indicates a lower fattening and heat-producing power than in alfalfa.

Tannin.—Tannin is an astringent principle found in many plants. Aside from its astringent properties, it is acrid, and therefore offensive to the palates of animals. In the stomach, it precipitates the pepsin and peptones, thus preventing the formation of dextrose and hindering digestion. Great thirst and constriction in the digestive tract usually follow an overdose of it. These effects are not so marked in some tannins as in others, for some do not have so great a precipitating power as do others.

In determining the tannins in the oaks, it was found to vary greatly in the different species, but did not serve as an infallible indication of the value of the leaves for forage. For example, *Quercus douglasii*, which is the poorest forage oak analyzed, is lowest in tannin, while *Q. dumosa*, a species preferred by sheep and goats, contains 13 per cent, the largest amount of tannin determined in any one species.

The average of tannin for all the oaks is a little over 10 per cent. In tasting the powdered specimens of the various species, the intensity of acridity perceived coincides with the tannin percentages. In comparison with oak leaves, alfalfa contains an inappreciable amount of tannin.

Water.—Although the water-content of the oak leaves was placed on an alfalfa hay basis, this does not indicate their true comparison when both are green. Green alfalfa contains 80 per cent of water, which is from 10 to 20 per cent higher than that in the various species of oaks. This shows the oak leaves to be a somewhat more concentrated feed in regard to protein, ash, and nitrogen-free extract, than appears in the comparison on an alfalfa hay basis.

Injurious Constituents.—Judging from the results of the chemical analyses of these oak leaves, they would seem to occupy a high place among forage plants. This would be the case were it not for excessive amount of three of the chemical constituents; namely, crude fiber, resins and waxes, and tannin.

The high percentage of crude fiber taken together with the low percentage of nitrogen-free extract produces a coarser and less nutritious feed than leguminous crops.

The resins have pungent and disagreeable flavors, which render them distasteful to stock. A good example of this is seen in the *Quercus californica*, before cited. The leaves of the young trees and shrubs of this species contain no more tannin than those of most of the other species, are only 1⅓ per cent below alfalfa in nitrogen-free extract, have a fair amount of protein, are low in crude fiber, and are large and soft.

These qualities should produce a feed superior to oat hay. This is not the case, however, for stock avoid it to a great extent on account of the resins and waxes in the dense tomentum covering the leaves. These waxes and resins serve as a protection against drying winds and severe weather, and all the oaks have more or less of them.

As compared with the crude fiber and resins, tannin of oak leaves, as before stated, is not only bitter and astringent, but interferes with digestion.

Conclusion.—In summing up the value of the forage oaks, from chemical analyses and observations in the field, the conclusion is reached that the facts observed in the field coincide in most cases with those determined by analysis. For instance, the deciduous oaks possess a higher nutritive value than the live oaks and are, as would be expected, more readily eaten by horses, cattle, sheep, and goats. In some cases, however, certain physical conditions modify these relations. This is true in the case of the live oaks. These contain a sufficiently high proportion of nutrients, and yet only sheep and goats thrive upon them. This is due to the thick, harsh leaves with their spinescent teeth, which prevent horses and cattle from relishing them.

Pasturing Oaks.—Although all stock prefer the deciduous oaks of the higher altitudes, yet indiscriminate pasturing causes much damage to the forests and ground-cover. When sheep and goats are allowed to browse on the deciduous oaks of the timbered area, they kill the seedling conifers by nibbling and trampling, kill the shrubs by over-browsing, and cut up the slopes in trails which become deep gullies during the rainy season. This could be avoided by pasturing the sheep and goats on the "live oaks" of the lower chaparral or brush areas, the only necessary precaution being to prevent too many congregating in one place, thus avoiding too much trampling and gullying.

Since cattle and horses are unable to thrive on the live oaks, and since they do not browse close enough to kill shrubs, never browse on young conifers, nor cut up slopes by trails, they may profitably be pastured on the timbered areas and on the higher altitudes.

Thus, this oak area, comprising half the whole State, can, by a conservative and well-regulated system of browsing, be made to pasture sheep and goats throughout the year, and all stock during the summer months; and also during seasons of drought or when winter conditions make other feed inaccessible.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS.

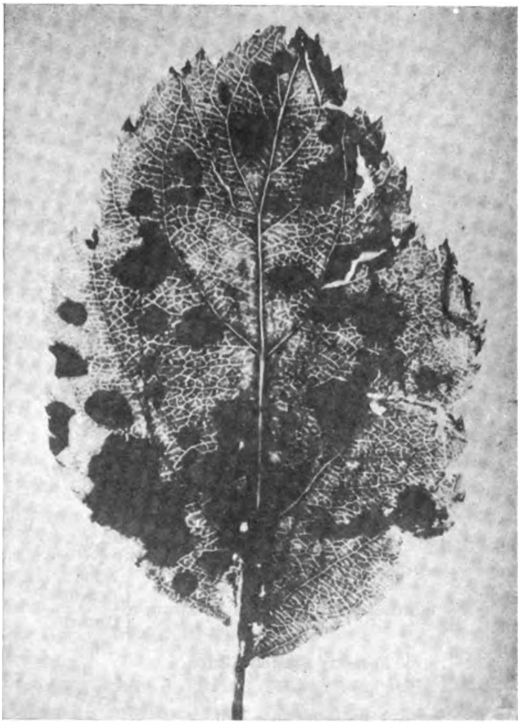
COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

ARSENICAL INSECTICIDES.

PARIS GREEN; COMMERCIAL SUBSTITUTES; HOME-MADE ARSENICALS.

BY GEO. E. COLBY.



APPLE LEAF "BURNED" BY PARIS GREEN.

BULLETIN No. 151.

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SACRAMENTO:

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1903.

BENJAMIN IDE WHEELER, Ph.D., LL.D., *President of the University.*

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SULFUR SPRAYS FOR RED SPIDERS.

The present Bulletin is based on the results obtained in the coöperative investigations of the Los Angeles County Board of Horticultural Commissioners, the Sutter County Board of Horticultural Commissioners, and the Entomological Department of the Experiment Station. Mr. Volck, a student in entomology at the University, working under the direction of the Entomologist, served as inspector in the two counties while the investigations here reported were being conducted. Special acknowledgments for assistance are due to Mr. J. W. Jeffreys, secretary of the Los Angeles Board; to Messrs. Payne and Seeley, Horticultural Inspectors of Los Angeles County; and to Messrs. Stabler, Kells, and Hull, Horticultural Commissioners of Sutter County. The formulæ now offered seem to meet all the requirements for the successful control of these pests on both citrus and deciduous trees.

C. W. WOODWORTH.

Red spiders (a family of plant-feeding mites) appear as minute brownish-red, red, or yellow specks, found either moving about over the surface of the leaves or resting in protected places on the stems. Their eggs can easily be seen with a magnifying glass. In the case of

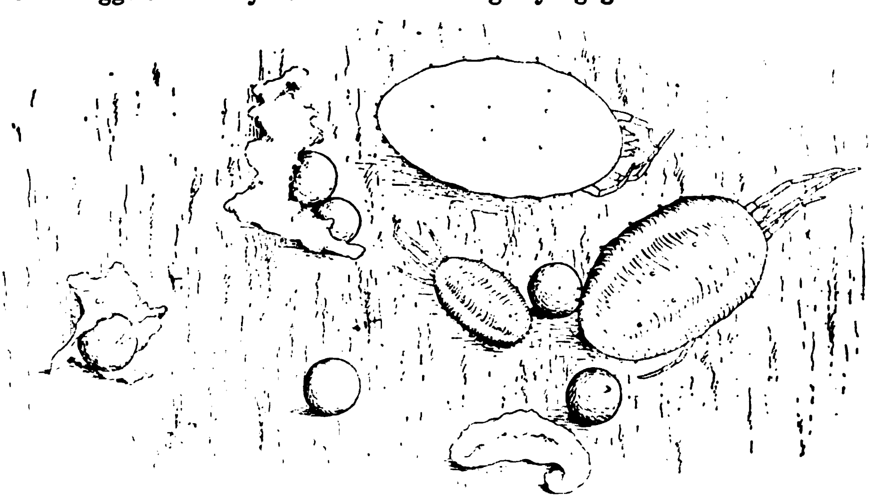

FIG. 1. THE EGGS, SHED SKINS, AND MOLTING FORMS OF THE RED SPIDER OF THE ALMOND.

the red spider of the orange, they will be found in numbers along the mid-rib on the upper side of the leaves, but are often found elsewhere. They are round, red before hatching, and white afterward. The eggs of the almond *Bryobia* are also red, but are usually deposited on the stems. The larger white specks and masses found on leaves and stems infested with mites, are composed of the shed skins of the young mites, for they molt several times before reaching the adult stage.

SPRAYING WITH DISTILLATES.

INTRODUCTORY NOTE.—The "spotting" of oranges results in considerable losses to growers of this fruit, and many causes have been assigned as producing it. Some of these alleged causes certainly have no relation to the trouble at all. Spots can be produced by mechanical injury, or by chemicals used to kill insects. Commonly one can readily distinguish between the spots due to either friction, fumigation, or distillate spraying; and can also distinguish these from spots caused in other ways. Growers usually fail to realize the possibility of a variety of causes, and assign the whole difficulty to one or another of the real or supposed sources of the trouble.

Spraying with distillates has probably caused more loss by spotting than any other one thing.

The study of this subject was first undertaken by this Station some two years ago. Further studies and observations of the results of field operations were made last summer, and finally in connection with the study of the red spider of citrus trees, reported in Bulletin No. 145, Mr. Volck was able to bring out of the work the conclusions presented in the following pages. This Bulletin, therefore, may be considered as in part representing further results of the coöperation between the Los Angeles County Board of Horticultural Commissioners and the Entomological Department of the Experiment Station of the University of California. Mr. Volck has opened the way to a much clearer appreciation of the problems of distillate spraying than has heretofore existed.

C. W. WOODWORTH.

In sections where the refined distillation products derived from crude petroleum are used as insecticides, it is common to speak of spraying with "distillate" as though referring to a single definite substance. But such a wide range of oils and preparations of oils are used, that this may be very misleading; since an opinion based upon the results of any one of them would not by any means apply to all. It would be less confusing, therefore, to speak of these products in the plural sense as distillates.

The term "distillates," when applied to petroleum products, refers to any oils derived from crude oil by distillation. Crude oils are obtained from wells tapping natural reservoirs of petroleum in the rocks. The oils obtained from different wells may vary in a marked degree in their composition, but most Western oils differ from the Eastern petroleum, and resemble each other to the extent that they contain asphaltum instead of paraffin as their solid base. If any of these oils are placed in a retort and distilled, the distillates will be driven off in the form of vapor, which condenses into oil on cooling. This first distillation retains considerable asphaltum and has a dark color. It is known as "green" or raw distillate. If the green distillate is now redistilled and the oil condensed while the retort is heating to successively higher temperatures, a set of oils can be successively collected corresponding to their different boiling points.

These oils correspond to definite chemical compounds with successively larger amounts of carbon, but are not sharply defined; since a heavier oil will begin to pass over before all the lighter oil has evaporated. In most refined products there is more or less a mixture of light and heavy oils. These oils belong to the benzine series; but each thus contains other oils of the same series and is charged with greater or less quantities of other substances occurring as impurities. To remove these substances the oils may be treated with sulfuric acid, then with caustic soda, and finally filtered through sawdust to remove water and water-soluble materials, after which they are called "treated distillates."

The naphtha and kerosene obtained by distillation of Western oils are not often used as spraying materials, although kerosene might be used advantageously in some cases. Likewise the heavy lubricating oils are not regarded as suitable for spraying. The distillates most used are those approximating 28° gravity (28° Baumé), and there is some disposition to use as low as 26° gravity. These oils lie between the kerosenes and the lubricating oils, and have some of the properties of each. They dry more slowly than kerosene, have a characteristic odor, and when clarified range from nearly white to a deep yellowish-brown color.

The accompanying table of analyses, made by Mr. Colby of this Station, shows the composition of some of these distillates.

There are two ways in which 28° distillate may be prepared: first, by mixing oils of higher and lower gravity; and second, by direct distillation—the so-called short-cut method.

The *short-cut distillate* resembles the mixed oils in containing oils of both higher and lower gravities, but there is less range; by far the greater part of the oil corresponds closely to the gravity indicated, and in the case of 28° gravity may be considered a nearly pure "gas distillate." The short-cut process for the production of spraying distillates is used much more now than formerly.

TABLE I. COMPOSITION OF "GAS DISTILLATES." By G. E. COLBY.

	"Gas Distillates" from Los Angeles Refineries.					From San Francisco Refineries.		
						"Gas Distillate."	"Petroleum Distillate."	
Manufacturer, or sender	Densmore-Stabler Co	Southern Refining Co.	The Asphalt Refining Co.	Hercules Refining Co.	Franklin Refining Co.	W. P. Fuller & Co.	Paraffine Paint Co.	
Color	Brown.	Blue.	Light brown	Green.	Black.	Brown.	Light brown.	Dark green.
Analysis. Degrees Baumé	26	26	28.5	25	27	29	27	22
	Per Ct.	*Per Ct.*	*Per Ct.*	*Per Ct.*	*Per Ct.*	*Per Ct.*	*Per Ct.*	*Per Ct.*
Gasoline	None	None	None	None	None	None	None	None
Benzine	None	None	None	None	None	None	None	None
Naphtha	3.1	1.2	None	1.2	1.5	None	None	1.6
Illuminating Oils	26.5	45.4	89.00	28.1	53.1	None	34.5	13.1
"Gas Distillate"	22.5	37.2	6.20	29.3	17.5	75.00	40.6	8.3
Lubricating Oils	46.1	14.7	4.63	39.3	26.6	23.80	24.31	74.3
Asphalt	1.8	1.5	.17	2.1	1.3	1.20	.59	2.7
Totals	100.0	100.0	100.0	100.0	100.0	100.00	100.00	100.0

These results show that only one of the above, viz., No. 112, is probably a true gas distillate containing none of the light kerosene, benzine, and naphtha products, while all of the others contain from 14.5 to 89 per cent of these light products of distillation. They may be considered as *crude oils*, or mixtures of light and heavy oils, so blended as to have approximately a gravity of 28° Baumé.—G. E. C.

Method of Use.—The most practical way to use oils as insecticides is to dilute them with water. This is rather a difficult matter to accomplish, since oil will not dissolve in water. Various methods have been devised to accomplish the mixing of water and oil. These may be divided into two classes, the emulsions and the mechanical mixtures.

Emulsions.—The mechanical mixing idea antedated the emulsions, but as first handled it was unsatisfactory, owing to the imperfect nature of the machinery used. In order to overcome the disadvantages of the mechanical process two forms of soap emulsions were devised, one by Professor A. J. Cook, and another by Professor C. V. Riley and his assistant, Mr. Hubbard. Eastern kerosene was employed, and for a long time this was the only oil used in spraying.

Kerosene emulsions, when prepared with care, are stable and very satisfactory as spraying materials; they have had wide application in the East, and to a less extent also on this Coast. The relatively high cost of this oil limits its availability as an insecticide.

In recent years, with a view of obtaining a cheaper insecticide, many other oils have been tried, notably California distillates; but it was at once observed that the light kerosenes prepared from these Western oils did not emulsify well, and when used on the trunk of the tree in large quantities for scale insects, the separated oil often accumulated at the surface of the ground and resulted injuriously. This difficulty was partly overcome by using heavier oils, and gas distillate of 28° Baumé became quite generally adopted.

The emulsions made from California oils have not usually been as satisfactory as those from Eastern kerosene, and a large amount of damage has been done by separated oil, which rises to the surface in the spraying tanks. The desire of the sprayers to be economical of material causes them, when the tank gets low, to finally spray this separated oil onto the trees.

Permanent emulsions are prepared by breaking the oil up into fine particles in a fluid which has sufficient surface tension to prevent them from readily uniting together. The small size of the droplets decreases the natural tendency of the oil to rise to the surface. When milk is used as an emulsifier a compound emulsion is produced, the casein particles coating the oil globules.

Soap is the cheapest, and therefore ordinarily the best emulsifying material. Soaps differ much in their emulsifying properties. Whale-oil soap usually gives very satisfactory results, as do also certain vegetable soaps. In place of these, common laundry soap, which is cheaper, may be used. The standard formula for kerosene emulsion is:

	Riley.	Cook.
Soap	½ pound	½ pound
Water	1 gallon	1 gallon
Oil	2 gallons	1 quart
Dilute with water, after emulsifying, to	30 gallons	4 gallons

With 28° or 26° distillates a pound of soap (dissolved in a gallon of water) to a gallon of oil gives good results. In preparing the emulsion the soap is dissolved in the water by boiling, and the oil is added while this spray solution is hot; the whole being churned very vigorously until the emulsion is formed.

Other emulsifying materials have been used, such as sour milk, and the juice of such plants as the soap plant (*Chlorogalum*).

But the preparation of stable emulsions is a difficult matter and it will not be necessary to go deeply into the subject in this bulletin, as they have largely been superseded by mechanical mixing methods.

The emulsions have proved unsatisfactory, primarily because of the difficulty of obtaining a stable article. If the oil separates and rises to the surface and is then pumped on the foliage in a pure state, great injury may result; in fact, the largest part of the serious injury to trees credited to distillate sprays may be traced to the bad effects of the separated oil.

Mechanical Mixtures.—While the mechanical mixing idea preceded the emulsions, it is only in recent years that it has been perfected and made practicable. There are several types of machinery which may be used to form mechanical emulsions, but they all operate to break up the oil into fine particles and keep it suspended in water by some kind of agitation. All such methods require the constant use of power to keep the oil and water mixed. In several spray outfits the entire body of the oil and water carried into the field is rotated or churned by means of a paddle working at such a speed that the oil is mixed with the water and broken up into such small particles that the mixture looks milky. This mechanical emulsion is then pumped through the nozzles and applied as a spray.

In other machines the oil and water are carried in separate tanks and mixed in the process of pumping. The oil and water may be drawn into a single pump and the proportions regulated by valves; or separate pumps of different sizes may be used. With this system a baffling chamber or cylinder is sometimes used. In the baffling chamber obstructions are placed, so that when the mixture is passed through it there is considerable friction, which is intended to bring about a more perfect emulsion.

Mechanical mixing represents the most modern idea in practical spraying, and is certainly a great improvement over the "stable" emulsions, which were so only in name.

In the case of citrus fruits there is another reason why the mechanical mixtures are superior to stable emulsions. The spotting of the fruit, which is due to the accumulation of oil by the drying of the large drops which form on the under side of the orange, is noticeably greater with these emulsions.

The oil in the latter is practically all held in the drop until the water evaporates, when the emulsion breaks down and the distillate penetrates the rind. In the mechanically mixed drop, however, the oil separates more quickly and seems to spread out over a relatively greater surface, and for this reason may not do much damage.

OILS AS INSECTICIDES.

The distillates are not the only oils having insecticidal properties; in fact, nearly all oils are capable of killing insects; but it is the volatile oils that are most effective, their vapors having far greater penetrating power than the oils in the liquid form. Death by suffocation, due to the clogging of the breathing pores of the insect, is only possible with the heavier and more slowly-drying oils, and death in this manner even with these is only a matter of conjecture. Commercial distillates contain a wide range of oils so brought together as to make up their definite degree of gravity. Some of the heavy oils found in the distillate may be very slow-drying, while the lighter parts will be correspondingly volatile.

This mixture of oils is apparently more effective than the pure volatile products, which may be explained on the ground that the heavy oils prevent the too rapid dissipation of the volatile parts. While the vapor is doubtless the condition in which oils exhibit their more evident insecticidal effect, the oils are certainly most effective when the liquid comes in immediate contact with the insect. The vapor given off by oil which has been sprayed on parts of the tree not infested with insects is usually too much, or too diluted by the air, to be effective on the parts that are infested.

Insects capable of motions show signs of great irritation and weakness when brought into contact with small particles of a volatile oil. But if the dose has not been too large, recovery always takes place.

The black scale, which is stationary during the greater part of its life, is not capable of exhibiting other symptoms of the effect of an oil than the loosening of the insect's grasp on the tree, so that it will "slip" much more easily than when not affected. This loosening is noticeable a few minutes after spraying, and is possibly due to two causes: the weakening of the insect itself, causing the muscles of the labium to relax, and the softening of the gummy matter which the insect secretes under its body and which helps to hold it to the tree. With this insect also, recovery may take place, and insects which are quite loose soon after spraying will often regain their hold.

It is possible, by increasing the amount of oil applied, to arrive at a point where all insects will be killed; but the difference in the resistance of the insects and the plants infested by them may not be great enough in some cases to allow the use of oil without danger to the plant.

PENETRATION OF OILS INTO THE PLANT.

By far the greatest cause of injury to vegetable tissues is brought about by the penetration of the oils applied, into the interior of the plant. Any one who has examined carefully a plant which has recently been sprayed with a distillate, especially one made of the heavy oils, will notice blotch-like spots beneath the surface which are somewhat darker than the surrounding tissues. (See frontispiece.) These spots are evidently due to the presence of oil which has penetrated the tissue of the plant, and owing to its slight volatility this may remain for weeks or even months.

Leaf Structure.—The rate of the penetration of a fluid into the leaf from the surface largely depends on the presence of appreciable openings through which it may pass, and when this fluid is in limited quantities other factors enter—such as the surface tension of the fluid itself, and the distribution of the oil on the leaf. Sometimes the surface of a leaf is smooth and free from hairs, as is seen in the guava and orange; while in other cases it is covered with a more or less dense growth of hairs, as in the morning-glory and quince. If a drop of oil is placed on an orange leaf it will not spread greatly over the surface, but if the same drop were placed on a morning-glory leaf the hairs would act as a wick, spreading the drop out over a considerable area. If the morning-glory leaves were as resistant to oils as are the orange leaves the injury would be far less.

If a drop of oil is placed on the upper and lower surface of an orange leaf it will be seen that the one on the lower surface will soak through the epidermis, while that on the upper surface will often remain until it evaporates. If the epidermis of the leaf is examined under the microscope, the upper one will show a comparatively smooth and unbroken surface, while the lower epidermis will be found closely sprinkled with openings known as *stomata*. A stoma is not a simple opening, but is provided with a valve-like arrangement of cells around it, which expand and contract according to the amount of moisture within the leaf and the relative humidity of the air. The presence of these stomata easily explains, then, the greater penetration through the lower epidermis.

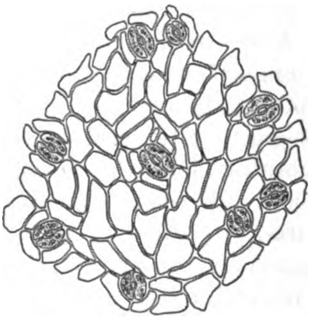

FIG. 1. A fragment of the lower epidermis of an orange leaf, showing stomata.

Again, if a drop of oil is placed on an orange leaf and the epidermis under it is punctured by a needle or other sharp instrument the oil will flow in very rapidly, showing that any injury to the surface of the leaf may help the oil to gain entrance. If this experiment is performed at the same time on the upper and lower surfaces it will be seen that as the oil spreads beneath the epidermis, forming regular patches with the point of entrance as a center, the patch on the lower surface will spread much faster than that on the upper one. The explanation of this is found in the structure of the inside of the leaf. (Fig. 2.)

Generally speaking, a section of a leaf at right angles to the upper and lower surfaces will show the cells to be arranged after the following plan: The upper surface is made up of a row of light-colored cells—the *epidermis*. These are thin-walled and empty in the case of the leaves of citrus trees. Beneath this is a layer of closely packed, elongated, and somewhat pointed green cells, arranged with their points toward the surface layer, or crosswise, of the section. These are known as the *palisade cells*, and in combination form the *palisade layer*. Under the palisade layer is a layer of large, irregular cells, which are loosely joined together, leaving spaces and passages between them. These cells are also green, but paler than the palisade layer. They constitute what is known as the *spongy layer*. The spongy layer extends to the lower epidermis of the leaf. The tightly packed palisade layer on the upper side gives little space for the spread of oil, but below this the loose structure of the spongy layer furnishes just the right sort of passageway for the rapid spread of the oils.

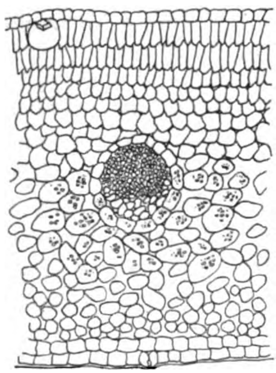

FIG. 2. Showing the internal structure of an orange leaf and a cross-section of a vascular bundle.

Aside from the green parts of the leaf there is the framework of *vascular bundles*, constituting the ribs and veins, which in some cases, notably the orange and guava (see Fig. 2), are buried within the layers of green cells; while in others, as the apricot (see Fig. 3), peach, and morning-glory, the vascular bundles connect with the epidermis both above and below. The vascular bundles are woody and compact structures, very different from the rest of the leaf. In the orange leaf the veins offer little resistance to the flow of the oil; but this is not the case with such a leaf as that of the morning-glory or apricot, where the vascular bundles uniting closely with the epidermis very effectively impede the flow of oil from one part of the tissue to another.

Diffusion of Oil.—This structural difference in leaves is a very important factor in the toxic effect of oils. Thus, for instance, in the orange leaf a drop of oil entering at one point may become diffused, spreading over so large an area that it may volatilize so soon as to cause little injury. On the other hand, in an apricot leaf, the oil being restricted by the vascular net to a small area, the same-sized drop will do injury before it can evaporate. With the apricot and morning-glory the penetrated parts are usually killed, the line of killing being irregular and following the vascular bundles.

It should be mentioned in this connection that the structure of the fruit rind of citrus fruits is in some particulars much the same as that of the leaf, there being stomata sprinkled over the surface, with green cell tissue beneath. Distillate penetrates the rind, and if a heavy oil, it remains for a long time, if not indefinitely, and thus forms the much-talked-of spotting.

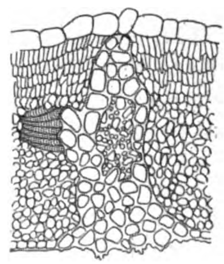

FIG. 8. Showing a cross-section of a vascular bundle of an apricot leaf.

Returning to the diffusion of oil through an uninterrupted spongy layer, it is evident that the capillarity of the oil must have much to do with the amount of the spread. The viscosity also, which tends to act against the capillarity by increasing the time required for a given body of oil to pass through a capillary opening, has its effect on the spreading. This is well illustrated by placing a drop of kerosene and a drop of a lubricating oil upon the same leaf; the kerosene quickly diffuses through the cell structure, while the lubricator acts much more slowly and never spreads as far. Thus the heavy oils, in addition to their slow drying, aggravate the difficulty by remaining locally concentrated.

Condition of the Plant.—Aside from simple points of structure, the condition of the leaf greatly affects the behavior of oils toward it. The flowing of oil through the cell interspaces is quite a different thing from the penetration of the cells themselves, or even the complete isolation of the individual cells, both of which must occur to some extent in the penetration of oils beneath the epidermis. Generally speaking, oil can not take the place of water, therefore an active cell well filled with water would be least likely to suffer in this way. But cells which are partly dried out and whose surfaces have become dry may be penetrated or sealed over by the oil. Thus the mechanical effects of oils are often sufficient to render parts of sprayed leaves functionless. If this isolation lasts long, it is alone sufficient to account for a large amount of the injury due to distillates. The age and health of the plant and leaf largely determine the amount or extent of the conditions which affect penetration. The older a leaf becomes, the rougher the skin and greater the probability of having received injuries. But the extreme young leaves, on the other hand, are more liable to be completely covered by a film of oil, and so killed. The old leaves are much drier and therefore more penetrable, and consequently suffer most if they receive the same treatment as do the younger leaves. However, on the tree such leaves are often so protected by the outside newer ones that in practice they often escape. In general, old leaves are most affected and the natural falling process much hastened.

CONDITIONS AFFECTING THE AMOUNT OF INJURY.

The greatest need for further work with oils is to determine their effect on plants under carefully determined conditions. A beginning has been made along a number of lines, but only that which has clearly led to definite conclusions can be now reported.

Quantity of Oil.—In order to determine more accurately the effect of oils on the plant, small quantities of oil were measured off and applied to leaves of definite sizes.

The branches chosen for the experiment were what are known as water-sprouts. These grow larger leaves than the fruiting branches and give a greater number on the same twig, which can be utilized for checks and experiments.

The practice was to begin with the lower leaves and work toward the tip of the branch, first applying a definite amount of oil to the under side of a leaf, then to the upper side of the next leaf, and, lastly, the same amount of oil was spread over both surfaces of a similar leaf. This operation was usually repeated three times on a sprout, and check leaves were left all along the stem. The data of two of these tests are as follows:

TABLE II. EXPERIMENTS ON LEAVES WITH DIFFERENT AMOUNTS OF OIL.

Eastern Kerosene. Applied November 28th.

Leaf No.	Area of each side of Leaf Surface.	Quantity of Oil Used. Upper Surface.	Quantity of Oil Used. Lower Surface.	Amount of Yellowing.	Date of Falling.
1	68.76 sq. cm.	---	.12 cc.	slight	--------
2	73.84 "	.12 cc.	---	slight	--------
3	81.53 "	.06	.06	slight	--- ----
4	57.69 "	---	.12	slight	--------
5	58.45 "	.12	---	slight	--------
6	56.66 "	.06	.06	slight	---- ----
7	42.92 "	---	.06	--------	--------
8	46.66 "	.06	---	--------	--------
9	38.35 "	.03	.03	--------	--------
		Short-cut 28° Distillate. Applied November 19th.			
1	69.23 sq. cm.	---	.05 cc.	slight	--------
2	70.30 "	.05 cc.	---	--------	--------
3	70.00 "	.025	.025	--------	Nov. 27
4	56.61 "	---	.05	--------	Nov. 27
5	51.57 "	.05	---	--------	--------
6	51.07 "	.025	.025	--------	Nov. 28
7	47.76 "	---	.05	--------	Nov. 28
8	42.79 "	.05	---	--------	--------
9	39.69 "	.025	.025	noticeable	--------

These experiments were repeated a number of times with various oils and dilutions, and brought out the following results:

First—The upper surfaces of the leaves were always able to resist amounts of oil which proved fatal when applied to the lower surface of corresponding leaves; but the oil applied to the upper surface had some effect, and often caused a slight yellowing of the leaves.

Second—When the same amount of oil as was used on a single surface was spread over both surfaces of a similar leaf it often caused the falling of the leaf.

Third—When the whole amount of oil was placed on the under side of the leaves, the result was about the same as when the oil was placed on both surfaces, causing falling and yellowing where similar amounts applied to the upper surface only were but slightly injurious.

It was often noticed that the large leaves near the base of the water-sprout showed serious effects from amounts of oil which the smaller and younger leaves at the tip resisted. This can be explained by the fact that these older leaves absorbed the oil much more readily, owing to their drier and rougher epidermis, while the young leaves were quite resistant to penetration and better supplied with water.

Character of the Oils.—Experiments were made to ascertain the effects of oil of different gravities. The oils were diluted to definite per cents with water in a bottle and shaken up until well mixed, when the mechanical emulsions, before they had time to separate, were poured over small branches. It was found that, among the oils tried under these conditions, the Eastern kerosene was the least injurious to the foliage, and that the amount of injury for a given per cent increased very rapidly with the gravity of the oil. Kerosene was found to produce no apparent injury on orange at 10 per cent, while the heavier oils were not free from injury at 2 per cent. It was also shown that orange foliage is much more resistant than that of the apricot.

The above experiments also illustrated, in a very interesting manner, the effect of *oils of different gravity.* The two records will serve to show the comparative effect of a 28° gravity distillate and Eastern kerosene. By comparing the preceding table it will be seen that for leaves of the same area and age an amount of *kerosene,* which was as large as the leaves could retain on their surfaces, was far less injurious than the much smaller amounts of *28° gravity distillate.* This heavy oil was manufactured by the short-cut process and said to be especially pure.

The *spray distillates* prepared by several refining companies were tried in the same way and showed similar results. There has been much contention in favor of clarified oils for spraying, but in our experiments little difference was found in them, except that the vapor of certain unclarified distillates proved more injurious to orange foliage than that from the best grade of short-cut clarified oils. This, as shown by direct experiments, is not due to any asphaltum or nitrogenous materials, but to benzines and volatile oils contained in the less pure products.

In our experience the injuries resulting from distillates are not due to any impurities contained in the oils, but to the oils themselves, and the only way to diminish these injuries is to choose less injurious oils, which evidently lie toward the kerosenes. Pure Eastern kerosene has given the best results, but certain cheap Western kerosenes have proved quite satisfactory. These can be obtained at nearly the same price as the clarified 28° gravity oils, so the only increase in the expense that would result would be the greater amounts of these oils required to be effective.

The Effects of Mixed Oils.—Some sprayers add turpentine and other light oils to the heavy distillates to enhance their insecticidal properties. The effects of the mixed oils on the plant are in general very nearly the average of the effects produced by these oils used independently, though the addition of 10 per cent turpentine to the 28° B. oil used does not materially change the result. Turpentine when used alone produces marked local injury and quick killing of affected parts, but has slight chronic effect, owing to its rapid evaporation. When mixed with the heavy oils, turpentine does not show these local effects in dilutions of 10 per cent or less.

If kerosene and the heavy oils are mixed, the moderating effect of the former is soon noticed. This is well shown by the following experiment; but as the branches experimented with had to be taken on different trees, the results are not in perfect ratio to the per cent indicated: Mixtures of kerosene and Southern Refining Company's 28° B. (short-cut) distillate, varying from 1 to 100 per cent, were applied to thirty-three branches of Valencia orange trees on the 22d of November, 1902. The branches were chosen in nearly the same position on the trees, and all were in about the same condition of fruit and foliage. The dilution was 4 per cent. On the 26th of December, 1902, the branches were all removed and arranged in the order of the apparent injury resulting.

Beginning with the most normal samples the per cents of kerosene in the mixture read 100, 90, 80, 70, 60, 30, 32, 34, 26, 28, 50, 24, 19, 18, 20, 19, 16, 15, 17, 10, 12, 11, 13, 14, 9, 1, 6, 5, 8, 7, 3, 4, 2.

The effects of the applications varied from almost nothing with pure kerosene to serious defoliation and loss of color with the lower per cents, showing clearly the injurious effects of the heavy oils.

General and Local Injury.—Along with the quantitative work a series of experiments were made to determine the *parts of the plant* where oils can do the greatest injury. With the citrus tree, leaves often break off at the junction of petiole and blade without showing any other signs of injury. It would seem from this that the injury was done at or near this point; but that this is not the case was shown by many experiments.

In one set of experiments oils and vaselines were applied to the petiole and blade at and near the point of juncture, but falling did not take place, although the doses used were often strong enough to kill the soft green pulp.

In a second set of experiments large areas at the base of the leaves were treated successively with oils, both upper and lower surfaces, and lower surface alone. In these experiments, while the parts covered with oil soon became yellow, the leaves did not fall unless the area covered was at least half of that of the whole leaf; but the same effect was obtained by coating the outer half of the leaf.

These experiments were repeated often enough to give perfectly definite demonstration, and they show that the most important injuries caused by oils are general and not local.

In the same way oils were applied to twigs and petioles, without coating the leaves. Here the leaves remained sound, but fermentations were set up in the stem which caused the production of gum; and very marked gum disease can, therefore, be produced by oiling the stems with a slow-drying oil like vaseline.

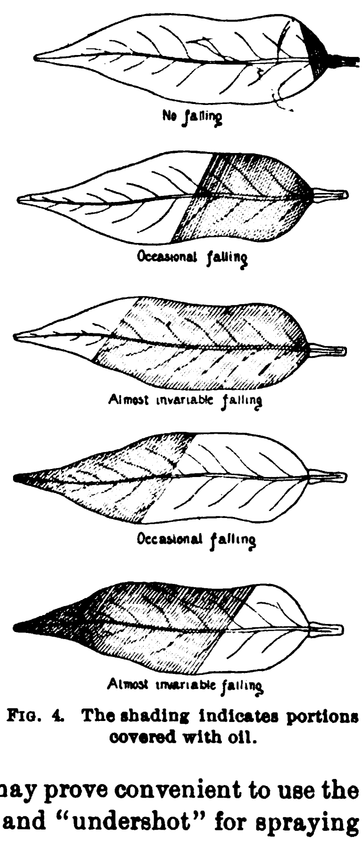

FIG. 4. The shading indicates portions covered with oil.

METHODS OF APPLICATION.

The different methods of applying oils and the results are illustrated in the accompanying figures (Fig. 4).

From the small experiments mentioned above, it was seen that the upper side of a leaf is several times more resistant to oils than the lower surface; some experiments were therefore conducted with a view of applying this principle in spraying.

Overshot and Undershot Spraying.—It may prove convenient to use the term "overshot" for downward spraying, and "undershot" for spraying upward. If emulsions or mechanically mixed oils are sprayed on the tree, always directing the nozzle downward, the upper surfaces of the leaves will be wet together with considerable more than half the surface of the branches, for the applied liquid runs around the twigs and branches, often completely wetting them.

Large branches of orange and grape-fruit were sprayed as described above with various 28° gravity distillates, a dilution of 4.5 per cent being used. Other similar branches were sprayed with the same dilution from beneath, throwing the spray only on the under side of the leaves. Still others were sprayed in the ordinary manner; that is, both from above and beneath.

These experiments were repeated a number of times with similar results, as follows: In all overshot work the foliage was very little injured, and in all undershot and normal spraying the injury was very serious.

All the branches sprayed were well infested with black scale, and it was found that the overshot method killed quite as many as would be killed by normal spraying with 1.5 to 2 per cent doses, which are as great as the tree can stand.

The effect of overshot spraying on the fruit is not as promising as that on the foliage, as the large drops which run down from the upper surface are liable to spot the rind. This difficulty may be greatly obviated in practice by the methods described in the chapter on Practical Suggestions, on page 25.

The *duration of application* is all-important with the oils. This is due to the method of diluting with water a body insoluble in the latter, which, as has already been stated, consists in breaking up the oils into fine particles held apart by the water of dilution. As oils are sticky or adhesive in their nature, the small particles tend to attach themselves to solid bodies with which they come in contact. For example, the continued application of a 1 per cent dilution of oil to a branch for ten minutes might result in leaving as much oil on the exposed surface as a dilution of 10 per cent applied for one minute.

The *manner of application* further implies the force and method used. It is clear that a spray thrown against the plant with considerable force will penetrate more than one which strikes lightly. Mist sprays are for this reason theoretically best for distillate work, but the nature of the foliage may modify this in practice.

With water-dilution of oils, it is impossible to get an even distribution of the oil over the surface, as the water collects in drops, and the contained oil is deposited in spots. Thus it may happen that an amount of oil too small to penetrate if spread evenly over the surface will do so when concentrated on small spots.

In this connection, some experimenting was done with a method of applying the oil free from water by means of an *air blast.* Here the diluting material was air; and consequently a particle of oil which landed on any part of the plant, did not change its position unless an excess was used, when running together took place. In this way, the maximum of oil can be applied to a given leaf surface without penetration.

Influence of Weather Conditions.—The *humidity* of the air largely determines the extent to which the stomata, or breathing pores, are open, and thus may influence the penetration of oils. In general, the stomata are more open in moist weather than in dry. They are, however, largely closed in very dry air, but here the extreme dryness of the leaf surface and of the pore openings lend themselves to the adhesion and inflow of the oils; so a dry day may not be as good a time to spray with distillates as one moderately moist.

Temperature seems to affect penetration, at least it has a very marked effect on the final results. Theoretically, with higher temperatures the oils are thinner and hence are better adapted to capillary flow. Another potent factor in this connection is that the high temperature in this climate is usually accompanied with low atmospheric humidity, and so adds to the effect of the latter.

NATURE OF INJURY PRODUCED BY OILS.

There are, doubtless, two kinds of injury produced by oils, which we may denominate chemical and physical.

Physical Injuries.—The physical injury from oil is due to insulation or sealing-over of parts of the plant, preventing the access of air to the inclosed parts. Insulation is also of two kinds, external and internal. External insulation consists in coating the outer surface of the leaf, stem, or fruit, as the case may be, with an air- and water-tight covering. If this covering is of a volatile nature it will pass away before any harm results; but if it remains for a considerable time, much of the characteristic injury resulting from the use of the distillate can be obtained with substances of a different nature.

The effect of external insulation would necessarily be of two kinds: first, the *prevention of the loss of water;* and second, the *exclusion of the air*, the oxygen and carbon dioxid of which are essential to plant life.

The *normal loss of water*, or transpiration of a plant is very great, and if interrupted there must result some disorder in the parts affected. The following simple experiments serve to illustrate the point in question:

A set of leaves was taken from a growing plant and part of them coated with vaseline; some on the upper surface only, some on the lower surface, and the others on both surfaces; all being put in a cool place along with the check or untreated leaves. Observations made from time to time showed considerable difference in behavior. The check leaves soon dried up, and were followed somewhat later by those greased on the upper surface only; while those treated on the under and on both surfaces remained unchanged for a long time; those coated on both sides lasting the longest. Vaseline has been used in several external experiments, but has one objection, viz.: When it is heated up to 80° F., or thereabouts, it is more or less liquid and will penetrate as other oils do. It is, however, a neutral substance and can not, except when very old, exert any chemical effect.

In order to determine the amount of water given off by living leaves treated with vaseline in the above-mentioned ways, they may be inclosed in glass tubes without severing them from the plant, and the amount of condensation of water noted. A record of one such experiment shows the following results: Four orange leaves, each having an area of about 20 sq. cm. on each side of the leaf, were inclosed in test-tubes, two checks and two treated—one coated on the upper surface and one on the lower surface. An examination one week later showed an abundance of condensation water in the check tubes and also in the one containing the leaf treated on the upper surface; but that containing the leaf treated on the lower surface showed only a very slight condensation on the surface of the tube. Twenty days from the beginning of the experiment the tubes were removed and the condensation water measured:

First check .... 0.9 cc.
Second check, dried up since former observation.
Treated upper surface .... 0.5 cc.
Treated lower surface (fallen from petiole), water not a measurable quantity.

Results similar to these were obtained in other experiments, and show in a very striking manner the possible effect of distillates on the transpiration of plants.

Insulation experiments were tried with other substances, such as paraffin, plaster-of-paris, etc., and the results agree with those cited above.

The other possible effect of external insulation, namely, exclusion of the air from affected parts, may be demonstrated to some extent by covering ripe fruit with paraffin. Some oranges treated in this way and kept in a cool place along with the checks, showed, after three weeks, a marked souring of the juice. This particular sample at this time showed no decay of the rind. Two weeks later the wax on the remaining sample was much inflated with gas bubbles and the rind showed some fungous decay. The checks meanwhile kept perfectly. The well-known observations on the behavior of plants placed in a nitrogen atmosphere may be cited in this connection. Strasburger, in his text-book of Botany, describes the effects produced as follows: "By placing them, for example, under a jar containing either pure nitrogen or hydrogen, or in one from which the air has been exhausted, plants previously growing vigorously cease their growth; the streaming motion of protoplasm in the cells is suspended. Motile organs of the plant become stiff and rigid and sink into a death-like condition"; and further, "In every condition of rigor, internal chemical changes take place, which, by a prolonged exclusion of oxygen, lead to the destruction and disorganization of the living substance."

The effect of oils in internal insulation is much the same as in the external, but here individual cells are involved and consequently another source of injury may exist, namely, that of insulation of the cells from one another, which would lead to still further complications.

Internal insulation is a more serious problem in practical spraying than the external, for the reason that it is most liable to occur. Less oil is required to effect a complete covering, because it is protected from evaporation, and hence remains for a long time.

Two distinct kinds of injury result from insulation, and probably correspond to the two effects obtained by exclusion of air, assisted by prevention of transpiration. These injuries may be classed as *rapid* and *chronic*.

The *rapid injuries*, when a neutral substance is used, depend largely on the temperature, and consist, in the citrus plants, of a rapid falling of the leaves affected, without any apparent change in them. In warm weather, 70° to 90° F., this falling takes place in leaves treated with vaseline or paraffin, in from two to three days; but leaves treated in the same way may require two or three weeks to be affected in cool weather, say at 50° to 60° F. This difference may be due to the lack of transpiration, which allows the leaf to become hotter than it would at the same temperature in the normal state, and thus produces a sort of heat-killing. It is possible that the dropping may be brought about in another way. If the air is excluded from the greater part of the leaf, the heat which would normally bring about healthy cell action might cause the production of toxic substances; these would be communicated to the weak cork-forming cells at the base of the stalk and cause their death and desiccation and a consequent formation of the cork layer, resulting in the falling of the leaf.

The *chronic effect* is very different, being much slower. It also brings about a loss of color, a yellowing in the affected parts and consequent lack of growth or other processes, which may result in the fall of the leaf some weeks or months after the application. In the orange, the chronic effect of stem-coating often brings about violent exudation of gum, resembling the gum disease. This effect is also seen occasionally in ordinary distillate spraying, and is most evident when the spraying has been done in warm weather.

The yellowing is most noticeable in green orange fruit or leaves which have been treated with vaseline. In from three to four days the color of the fruit begins to lighten, and it may, in the course of a month, assume the brightness of the normal ripe fruit.

Chemical Injury by Oils.—The injury which is due to insulation could just as well be produced by *any* substance which would exclude air and retain water; but most oils have a direct chemical effect, induced by their vapor. If a growing plant is inserted into a bottle containing a small amount of oil showing this chemical effect, and the bottle is corked or sealed for several hours in such a way as not to break or harm the branch, the effect of the vapor may be noted. In this connection three tests made with orange foliage are worthy of note. In the first, a saturated gasoline atmosphere was used. Time of application, half an hour. Twenty-four hours later the tips of the leaves nearest the liquid gasoline in the bottom of the bottle were wilted, and later dried out quite white, otherwise the leaves appeared normal; but in about sixty hours a general bleaching was noted. (This was a *whitening* and differed from the yellowing previously referred to.) This bleaching was followed by the falling of all the treated leaves, which was complete in one hundred and twenty hours from the beginning of the experiment.

In the second experiment, Franklin Refining Company's 28° B. distillate was used. The leaves were exposed three and four hours respectively, with similar results. A decided bleaching of the treated foliage was noted in seventy-two hours, accompanied by the falling of the tenderest leaves of the new growth, namely, those just expanded from the bud; later, most of the older leaves fell.

In the third experiment, Southern Refining Company's 28° B. (short-cut) distillate was used. The application lasted five hours, and resulted in a decided bleaching of the lower surface of the leaves, which were also somewhat curled and distorted; but no falling took place.

The results of these experiments are sufficient to show that the chemical effect of oils is entirely different from that of insulation, although it brings about the same ultimate result, namely, the falling of the leaves.

The nature of this chemical effect is not so easy to explain as that of insulation, but it is safe to say that it is always present in spray distillates, although some show it less than others. This is probably the most important insecticidal feature of oils, and it affords the best method of explaining the very marked insecticidal effect of some of them. For instance, in hopper-dozer work it is sufficient that the insect touch the oiled surface with any part of its body in order to bring about death in a few hours. Insects are probably more subject to the chemical effect of oils than are plants, and may even respond in a different way.

With those oils which contain gasoline, the effect of their vapor on vegetable tissue is rather slow in developing, and partakes of a chronic nature, from which the affected parts recover slowly.

RESISTANCE OF THE PLANT TO INJURY BY OILS.

All plants are not alike in their response to distillates or oils, and the citrus plants were found to be among the most hardy in this respect. There is also considerable difference in the resistance in varieties of the same species. For instance, distillate spraying has long been considered a success on lemons, while it has not succeeded on oranges until the advent of the mechanical mixing process, and is even yet of doubtful utility. Grape-fruit is even more sensitive than the orange. All deciduous trees experimented with have proved very susceptible to injury by the distillates other than kerosene.

The nature of the injury to the orange and apricot foliage also differs somewhat; with apricot, the spots showing penetration were much more localized and the oil in each spot more concentrated, and consequently a withering of parts of leaves occurred, due to the rapid killing of the cells which were entirely surrounded by the oil. This greater localization of oil on the apricot leaf is due to the less penetrable vascular bundles coming in close contact with the epidermis (see Figs. 2 and 3, pp. 12–13), thus making dams which prevent the greater diffusion of penetrated oil, as compared with the orange leaf, where the bundles are buried in the green pulp between the skins. Corresponding doses of distillate are much more injurious to the apricot leaf, as a whole, than to orange foliage, notwithstanding the above-mentioned fact in reference to the localization trouble. In addition to the localized injuries, the leaves of the apricot treated with distillate became yellow, and fell, the petiole breaking from the stem as in the natural falling of an old leaf. The orange leaf, on the other hand, may not show any signs of injury, but will break off at the juncture of petiole and blade in from three to ten days from the time of treatment, falling taking place most and soonest in hot weather.

But injury is not confined to the leaves which drop. All treated leaves are more or less injured and recover very slowly from the effects of the heavy, slow-drying oils. A loss of color may be noted in from ten to fifteen days, and the leaf may never regain its former green appearance. The same dropping and yellowing effect that is seen in the leaves takes place with the fruit also. In fact, the young fruit is much more sensitive than are the leaves to the "dropping" effect of distillates. The yellowing effect is most noticeable in the class of plants to which the prune and apple belong. The color of the matured leaf may be completely changed in three or four days by the use of very weak dilutions of the 28° distillates, and from what has been observed in these experiments, most deciduous plants, when in leaf, should not be sprayed with the heavy distillates.

Variegated Leaves.—Chronic effects are induced by diseased and depleted conditions of the tree in general. The trouble known as *variegated* leaf was observed to render the trees affected by it quite sensitive to distillates. Also the yellow or dormant condition of the foliage and tree, due to lack of nitrogenous fertilizer, greatly increased the liability of injury from an oily spray material. The old leaves in a normal condition are very sensitive, being drier than the new leaves and in a slow state of vegetative activity. Such leaves will usually fall from any tree sprayed with distillates, a fact which is sometimes cited by sprayers as an advantage of the process; namely, the removal of old and useless foliage. But it must be remembered in this connection, that the cause which effects the falling of some leaves on a tree also operates in the same direction on *every* leaf, with a resulting depressing effect.

Effect of Temperature.—Another and very important feature in the resistance of plants to distillate effects is the temperature of the air. This was dealt with to some extent under the head of penetration, on page 11.

There are two possible ways in which a temperature of about 80° F. might affect leaves treated with distillates. The first relates to the insulation caused by the oils and the consequent checking of transpiration, or the giving-off of water by the plant. It may be roughly likened to a man hard at work and yet unable to perspire. He would soon become overheated and prostrated. In the same way the leaves of a plant might become overheated if the transpiration-current were cut off, except that in the case of the plant the heat must be supplied from the outside.

It has been demonstrated by experiment that insulation will cause the falling of a leaf in two or three days, if the leaf is in the direct sunlight or in a warm location; but leaves treated in the same way and kept in a cool place may remain on the plant for several weeks without change.

The temperature may also affect results by increasing the amount and rate of oil-vaporization, for if the vapor of an oil has any effect it will increase with the amount present, and perhaps this factor is as important as the heat itself.

Aside from the matter of variety, the condition of the plant largely controls its behavior toward distillates. Plants in vigorous growth are much more resistant than those in a dormant condition. This was constantly noticed in experimenting with the effect of oils. For these reasons distillates are most satisfactory where applied in the cool weather of the fall and winter.

PRACTICAL SUGGESTIONS.

The question of how far the use of an oil spray can be profitably carried with citrus trees depends on its effectiveness when compared with other methods of disinfection. As the spray kills by contact and soon evaporates, the effectiveness of any one operation extends over but a short period. Practically any insect not killed at once, escapes, although there is a slight tendency to chronic injury and slow death, just as in plants.

Repeated experiments and observations of distillate spraying-work done in citrus orchards in southern California have shown that large numbers of insects and mites escape the most careful spraying, and naturally this number increases with the dilution of the wash. In fact, it has been found necessary, in order to avoid serious injury to the trees, to dilute the sprays so much that the hardier and more protected stages of the various scale insects survive in sufficiently large numbers to quickly and completely reinfest the tree, if the treatment stops with one application.

In the case of the *black scale* the evidence in this particular is most complete. The first spraying with a 28° B. distillate of from 2 to 3 per cent dilution results in the death of most of the scales in the active growing stages, often killing scales nearly full grown. The results of such spraying can be determined by inspection in about a week after application. (The few that die later from the effects of the treatment do not affect materially the conclusions reached.) The dead scales will then be shriveled and many will have fallen from the tree. The majority of those living will be found to be old scales covering numerous eggs, which have also remained unaffected. In some cases the old scales may be somewhat loosened, thus aiding the emergence of the young from beneath the shell.

Quite often, an extensive appearance of young scales is noticeable in from two to three weeks after spraying. These and other young, which emerge from time to time, may reinfest the tree, making its condition as serious as ever in from six to seven months after the first spraying. Owing to this fact it is necessary to repeat the spraying two or three times, allowing some months between applications. The operations should be at least two months apart, the object being to reach as many as possible of the insects while still in their more sensitive condition, and to give the tree time to recover from the last spraying. The first spraying may so reduce the number of scales on a tree that all smutting and injury from this source ceases for the time being, and if the operations are repeated properly will often result in a fairly clean tree.

The *red spider* offers a somewhat different problem. Here the eggs are exposed to the action of the spray, and can be killed with from 1 to 2 per cent dilution of a 28° B. distillate; but in practical spraying many mites escape, presumably those which have not been touched by the spray, and the time which should be allowed to lapse between applications of the spray will often be sufficient for a complete reinfestation of the tree. Thus the control of the mites may be even more doubtful than that of the black scale.

Injury to Plant.—None of these sprayings can be done without more or less injury to the tree and fruit, but there are times of the year and manners of application which make it possible to spray with distillates without this injury being very serious.

The injury caused by distillates to the plant may be briefly summarized as, *first*, the rapid falling of leaves and young fruit, which takes place in from three to ten days after the application; *second*, the yellowing and slower falling of these parts, resulting from the prolonged or chronic effects of the distillate. The rapid falling takes place most and soonest in hot weather, and perhaps the chronic effects are also most felt at this time. The amount of injury resulting from spraying is also much less on healthy trees; that is, trees in good growing condition and not suffering from yellow-leaf, lack of water, or scale. As the amount of water in the plant can be remarkably increased by the watering of the soil, it would seem a good practice in hot weather to spray as soon after irrigation as possible, for at such times the plant would contain most water, and would therefore be less penetrable to distillates. But in general, the results from spring and summer spraying of orange trees have been such as to indicate that the plant will always suffer enough during these seasons to make treatment with distillates inadvisable. Not that the plant in general will be most damaged at such times, but that the young fruit is then most susceptible, both to spotting and dropping.

Spotting and Dropping of Fruit.—There is no doubt that dropping of young fruit is greatly increased by distillate spraying, and may even bring about falling of fruit in sizes which are normally beyond such a possibility. The brown spot or stain which appears on ripe fruit that has been sprayed during the season, is also most liable to be formed when the fruit is young; that is, from half-grown to within a few weeks of coloring. These spots may be noticed in the green fruit as somewhat duller and darker blotches just under the skin of the rind. They do not change much as the fruit grows older, and when coloring takes place they remain brown. Such spots do not injure the orange in any way except appearance.

It is hardly possible to spray with a heavy distillate (that is, 28° B. to 26° B.) without injuring young fruit by spotting or dropping. Then if it is intended to spray with distillates, it is not advisable to do so in the spring or early summer, but the best results will be obtained from October until January. In October the orange rind has developed and is much more difficult to spot than earlier in the season; also the weather is cooler, and the general effects of distillates on the plant are much less severe. Leaf falling will not be so noticeable, and yellowing of the leaves will not be so marked. The fruit is also naturally beginning to color at that time, so any artificial increase in this tendency will not be a detriment.

But it may be argued that the early broods of the black scale will be too large to be killed late in the fall. This would be a greater difficulty if it were not for the fact that most of the early brood die during the summer. It is either parasitized or dies from heat, and also from drought, which may put the tree in such a condition as to kill the scale. In this way the earlier broods of scale are often nearly eliminated from the problem of disinfection.

Two Sprayings Annually.—Now if the problem of fruit injury did not enter into consideration, the spraying in October or November should be followed by a second application at the time the scales, which hatched from the eggs not injured by the first application, had arrived in part at the maximum killable size. This would naturally insure the greatest efficiency to the second operation. But the scales might not reach this condition until well into the growing season of the following spring, when spraying with distillates is inadvisable. The second application should therefore be made in January and February, or just before the flower spurs start. The scales which escape that operation should be left again until October or November, when the routine should be repeated.

This provides for two sprayings a year, and yet may not be sufficient to insure perfectly clean trees; but such can not be obtained by spraying unless the treatment is planned wholly with regard to the scales, and not considering the most desirable time with regard to the plant. Three or four applications will be found necessary to clean badly infested trees and bring the efficiency of this method of disinfection up with that of proper fumigation.

The two sprayings a year, timed as before stated, are not only all that is desirable from the point of plant resistance, but also reaches the limit of the economic advantage which spraying has over fumigation; for experience has shown that *spraying will not be cheaper than fumigation if three or four applications are required.* Further, if a schedule of fall and early spring sprayings is adopted, it will also result in the best control of the red spider which can be obtained with two sprayings.

Where spraying is done early in the season, or during the spring and summer, the spider may be numerous again during the fall and winter, for distillates really leave a large number of mites alive, which by means of their rapid breeding may become abundant again in a few months.

If the spider is abundant in the late spring, early summer, or in the fall, sulfur spraying is advisable before spraying with distillates. The same machinery can be used, but the material will cost more. It is advised by some to use a weak distillate spray in such cases, but it must be remembered that the labor factor is the same as for a full straight dose, and it is not nearly so effective; besides, it is not possible to so reduce the strength of the distillate (28° B. or thereabouts) that it will not affect the plant, and especially the fruit.

PREVENTION OF INJURY FROM SPRAYING.

The question of injury to the plant is one of such serious consequence that any change in the manner or time of application which will reduce the same, is of consequence to those who wish to spray with distillates. Next in importance to the time would come the system used in applying the wash. The method which naturally suggests itself is to wet every part of the tree as thoroughly as possible, so that no insect may escape. In order to do this great care must especially be taken to wet the under side of the leaves. But the experiments detailed above have shown that the under side of a leaf is most sensitive to distillate injury, while the upper side is comparatively resistant. It is obvious that the spray hurled up under the leaves is proportionally much more injurious to the tree than that applied from above.

Overshot Sprays.—The overshot method involves spraying as nearly straight down as possible, beginning with the top of the tree and proceeding toward the sides and bottom. Ladders are necessary to apply this method to large trees, as the sprayer must see what he is doing. With this method it is possible to use about double the per cent of oil without as much injury as results from the ordinary strengths applied in the common way.

The overshot method wets much more than 50 per cent of the stems, but leaves most of the leaves dry on the under side; so if an overshot spraying was done with a 4 per cent dilution, and some ordinary spraying done with 2 per cent, the overshot spraying might kill the greater number of scales and at the same time do less injury to the tree. There are two difficulties in the practical application of the overshot method; first, the spotting of the fruit is not overcome; and second, the red spider, if present, will be left in large numbers on the under side of the leaves.

Whatever may be the chemistry and physics of the commoner form of fruit spot caused by distillates, it is evident that it is produced by the presence of the oil upon limited areas of the rind. These excessive amounts are large drops of the liquid left hanging to the rind of the fruit after the application has been made. The spots will be somewhat larger than the drops, owing to the spread of the oil beneath the rind. The oil in the drops becomes more and more concentrated by the evaporation of water, and is finally left in a free state on the surface of the rind, from whence it penetrates the tissue. This form of spot will be present to some extent on fruit sprayed by the overshot method. The part of the fruit exposed directly to the action of the spray is wet, and drops of the wash run down the sides and hang from the lower surface. The general surface of the fruit is, however, less injured by overshot spraying than by the ordinary methods.

Combined Spraying.—In view of the spotting and the red spider difficulties which still remain with the overshot method, it is evident that it will have to be supplemented if we would take full advantage of the greater resistance that the upper surfaces of the leaves have to distillates. If the overshot application is followed by a slight undershot spraying with a much weaker dose, the large drops of strong mixture left by the overshot application will be replaced by a much weaker mixture, but still of sufficient strength to kill the red spider. To make this plan successful the undershot application must be made very soon after the overshot, which would require the use of two machines: one to do the overshot work and one to follow doing the undershot. It is possible to modify the types of machines now in use so that both overshot and undershot work can be done by the same outfit.

The existing spraying machines can be modified for overshot work by placing a smaller pump on the piston rod, designed to carry somewhat less than one third the liquid thrown by the large pump. This small pump is connected with the discharge of the large pump and also the water tank by adjustable valves. The discharge of each pump is connected with a separate pressure tank and thence to the hose—the large pump supplies two lines of hose and the small pump one. In operation, part of the mixed water and oil thrown by the large pump is drawn into the small one and again diluted with water from the tank, so that while the large pump might be throwing a dilution of 4 per cent, the small one would deliver a 1 per cent wash, or any other proportions which might be desired. This mechanism overcomes the trouble with the very fine valve adjustment required to introduce 1 per cent of oil directly into the water.

This attachment can be placed on any form of machine. With the double suction patterns the oil is introduced into the large pump, and in the agitator machines an extra water tank must be carried to furnish the water for the small pump. The double suction machines are evidently best adapted for this attachment, because one water tank serves both pumps.

In this way two lines of hose could be used for the overshot work, applying the spray at from 3½ to 4 per cent oil content, while one line would be occupied with the undershot work, using a 1 per cent wash. The overshot application should be quite thorough, beginning at the top of the tree and extending down the sides, while the undershot operation might consist in rapidly going over the under sides of the fruit to remove the large drops. This would result in a slight wetting of the under side of the foliage, in most cases not enough to result in serious injury. Those who are not provided with such a machine may make some use of the overshot idea by applying most of the wash from above and throwing as little up under the leaves as is possible for thorough work.

There are also some minor points in application which should not be neglected. For instance, an excessive amount should not be applied, for the oil accumulates on the leaves, and the effect of a 4 per cent wash may be had with a 2 per cent dilution. Again, a very dashing, heavy spray will penetrate far more than a fine mist, but the nature of the orange foliage seems to limit the extent to which the mist sprays can be used. This is especially true when the tree is loaded with fruit. All the branches are then bent down and the leaves are held in place by the weight of the fruit. Under these conditions it seems necessary to use a somewhat coarser spray. Spraying outfits usually come equipped with satisfactory nozzles. These are nearly all modifications of the cyclone type. The favorite extension rod has two cyclone nozzles about a foot apart on a cross-arm, which is borne at right angles to the main rod. The nozzles are attached to this rod by means of an elbow. In this way there are no sharp corners or projections to catch in the tree. The nozzles of the Vermorel type, having a plunger for cleaning, are objectionable on this account.

Oil to be Used.—The question of the oil to be used in spraying work is quite important. In the early history of distillate spraying, attempts were made to use much lighter oils than those in more recent practice. At that time the emulsions offered the only means of handling the oils, and it was found very difficult to make very stable emulsions with Califorina light kerosenes, considerable injury being produced by the separated oil. For these reasons heavier oils have been used with better results, so far as emulsions are concerned; but apparently these heavy oils are far worse than the kerosenes in their general effect on the plant.

With Eastern kerosene it was found that 25 per cent of oil was less injurious than 5 per cent of a 28° B. Western distillate. The kerosenes are also somewhat less effective as insecticides, but not in proportion to their neutrality to plants. This is due to the fact that insects are much more quickly affected than vegetable tissue, and with a volatile oil the plant might escape injury where animal life would be destroyed.

A sample of Western kerosene tried did not give as good results as the Eastern article, but this was probably due to its greater content of benzine and gasoline, which substances are very volatile and severe in their action on plant tissue. But there is no reason why kerosene, sufficiently pure to be used in spraying, could not be prepared by the refining companies at a reasonable cost. Such oils could be used if they could be had for from 8 to 10 cents per gallon. The cost of the heavier distillates ranges from 5 to 7 cents per gallon, and the low per cents used make the expense of the material very small; but it is a question whether the orchardist prefers the cheapest, regardless of consequences. Kerosenes are now quite extensively used in Eastern practice, and the per cents run rather high, 25 per cent of oil content being more common there than 2 per cent with Western distillates.

The orange tree will withstand from 8 to 10 per cent of kerosene, used in ordinary spraying, and 15 per cent in overshot work. These strengths are sufficient to kill young scale and the red spider. Kerosene has the same limitations as the heavier oils, and several applications are required to clean a tree of most insects. It can also be applied to other than citrus plants with greater safety than the heavier distillates. In fact, kerosene oil has many points to commend it to orchardists who wish this kind of an insecticide, but in all cases an article reasonably free from impurities should be insisted upon.

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1900. Report of the Agricultural Experiment Station for the year 1897–98.

1902. Report of the Agricultural Experiment Station for 1898–1901.

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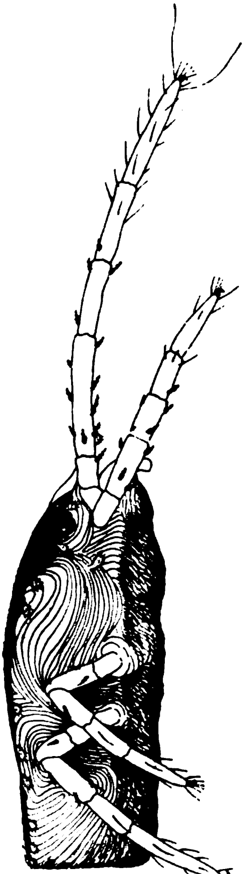

RED SPIDER, OR MITE OF THE ALMOND.

SULFUR SPRAYS

FOR

RED SPIDERS

BY W. H. VOLCK.

BULLETIN No. 154.

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