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Quantitative Assessment of Insect Pest Damage to Figs

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Abstract

Previous researchers have listed insect pests associated with figs, but the proportion of damage caused by these different pests has not been described quantitatively. As broad spectrum insecticides are being replaced by less toxic but more species-specific pest management methods, this information has become more important. We took harvest samples from three orchards in 2002, four in 2003, and six in 2004, and identified the insect pests responsible for defects among the samples. Diagnostic characteristics of damage to figs differed among common insect pests. Nitidulid beetles and navel orangeworm together usually accounted for > 90% of producers' losses to insect infestation. Losses from nitidulid beetles greatly exceeded those from navel orangeworm in the first year, but were similar in the remaining sites in the second and third year of the study. Mean infestation levels generally increased significantly as the harvest season progressed, but not at all sites. Producers should examine cull figs from their sorting lines over several years to determine which of these insect pests is most abundant in their locations.

Introduction

All commercial dried figs in the United States are produced in California, primarily in the San Joaquin Valley. The California fig industry produces several varieties of figs based on two types. Mission, Adriatic, Kadota, and others are based on the Common type, whereas Calimyrna is currently the principal representative of the Smyrna type in California (3). Calimyrna figs represent the greatest volume in the California fig industry, are the most valuable on a per weight basis, and differ from other varieties in that they require fertilization by the fig wasp *Blastophaga psenes* (L.) for fruit to mature (3). This necessitates a larger eye (apical ostiole) (3) compared to other varieties, making Calimyrna figs more susceptible to insect pests and diseases. Insect pests associated with figs in California were described in the early 20th century (5). Among the most important arthropod pests attacking figs in the orchard were the driedfruit beetle *Carpophilus hemipterus* L. (Coleoptera: Nitidulidae) and other *Carpophilus* spp., and the vinegar fly *Drosophila* spp. (Diptera: Drosophilidae). The raisin moth *Cadra figulillela* (Gregson)

(Lepidoptera: Pyralidae) was also noted as a pest of "well-dried, harvest figs." In the mid-twentieth century the navel orangeworm *Amyelois transitella* Walker (Lepidoptera: Pyralidae) became an abundant pest of horticultural crops in California, including figs (8). Insect infestation causes fig growers substantial loss, either when packers substantially reduce payments to growers for shipments of figs with greater than 13% insect infestation or, more typically, when growers aggressively sort out and discard infested figs to avoid penalties. While previous literature has described insect pests associated with figs, there have been no attempts to determine the proportion of damage caused by these various pests. Information available to growers about insect damage to figs comes primarily from market order inspectors. They assess figs as "insect infested" based on the type of damage present rather than on identification of insect or insect parts, and do not attempt to assess the species causing the damage. Determination of the proportion of damage caused by specific key pests has become more important due to recent trends towards pest management materials and techniques with lower non-target toxicity, and insecticides targeted for a narrower range of pests (4,7). Examples of such materials and techniques in figs include spinosad (6), which has recently received registration, or mating disruption against navel orangeworm, which has been examined on an experimental basis (1).

In this study, our objectives were to describe diagnostic characteristics used to differentiate damage caused by insect pests in figs, and to determine the proportion of damage caused by key insect pests and damage trends with successive harvests.

Identification of Insect Pest Damage

Damaged figs were obtained from harvest samples (described below), and types of damage diagnostic for navel orangeworm, nitidulids, and *Drosophilia* were determined by association of damage with dead insects inside the fruit. Damage was photographed using an Olympus Camedia C-5050 Zoom in macro setting, a Nikon D70 with a 105 mm lens, or a Vision Engineering Cobra dissecting microscope with a Nikon CoolPix 4500 camera.

Characteristics of undamaged dried Calimynra figs and insect damage diagnostic of infestation by nitidulid beetles, navel orangeworm, and *Drosophila* are shown in Figures 1 through 4. Dried figs of acceptable quality are characterized by evenly-spaced seeds surrounded by a shiny clear amber paste (Figure 1). Damage from nitidulid beetles is accompanied by a cylindrical or string-like frass (Figures 2A and 2B). Nitidulid larvae, when present, are best distinguished from other common insect pests of figs by the horn-like cerci on the posterior end (Figure 2C). While the large pupa of the navel orangeworm, covered by a webbed cocoon, is readily visible in this photo (Figure 3A), large larvae or pupae don't always accompany navel orangeworm damage. Silk and frass, which is rounded or globular in appearance (Figure 3A), is a more consistent diagnostic characteristic of navel orangeworm damage. Younger navel orangeworm larvae might be superficially similar to nitidulid larvae, but can be distinguished by the head capsule (Figure 3B), and by the absence of the cerci associated with nitidulid larvae. *Drosophila* larvae don't leave a readily identifiable frass like nitidulid and navel orangeworm larvae. Instead, the damaged part of the fig appears soft and is riddled with many small holes (Figures 4A and 4B). Areas of missing seeds are also typical of this type of damage (Figure 4A). *Drosophila* larvae can be distinguished from nitidulid and navel orangeworm larvae by the presence of mouth hooks (Figure 4C), and by the absence of cerci or a head capsule.

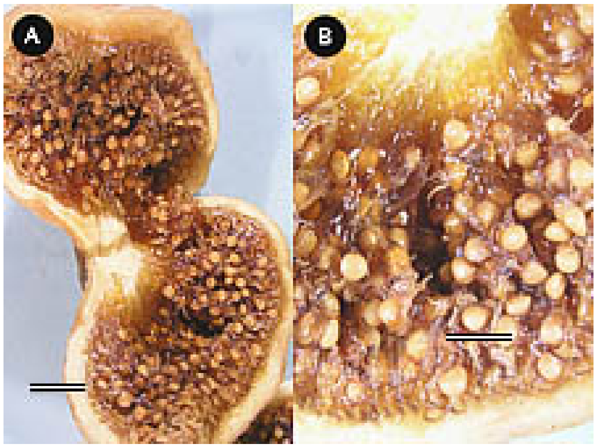

Figure 1. Characteristics of undamaged dried figs. (A) Clear amber paste; scale bar = 1/4 inch. (B) Detail showing paste and seeds; scale bar = 1/8 inch.

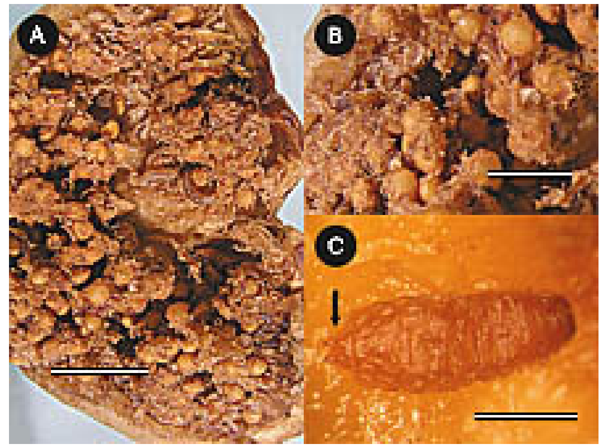

Figure 2. Characteristics of damage to dried figs by nitidulid beetle larvae. (A) Appearance of nitudilid frass; scale bar = 1/4 inch. (B) Detail showing appearance of frass; scale bar = 1/8 inch. (C) Nitidulid larva, with arrow indicating 2 pair of posterior cerci characteristic of nitidulid larvae. Scale bar = 1/16 inch.

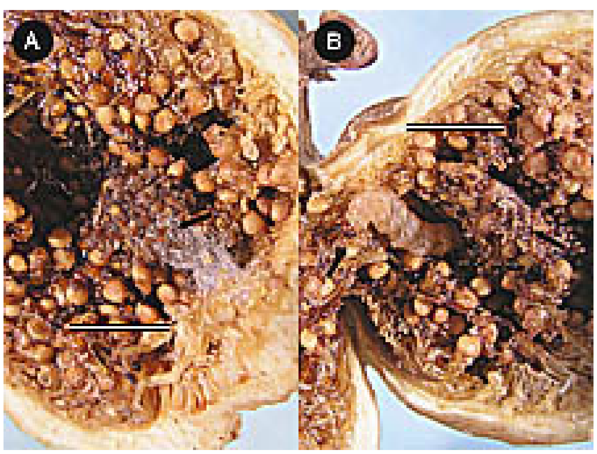

Figure 3. Characteristics of damage to dried figs by navel orangeworm larvae. (A) Appearance of navel orangeworm frass. Arrow indicates pupa with characteristic webbing. Scale bar = 1/4 inch. (B) Detail showing larva and form of frass. Arrow indicates head capsule characteristic of lepidopteran larvae. Scale bar = 1/4 inch.

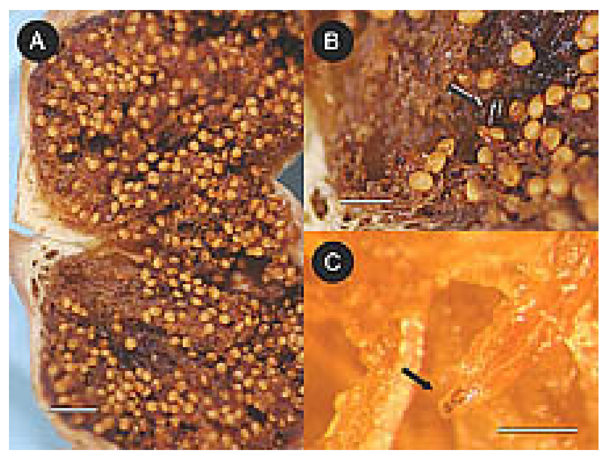

Figure 4. Characteristics of damage to dried figs by vinegar fly (Drosophila) larvae. (A) Appearance of Drosophila damage; scale bar = 1/4/ inch. (B) Detail of Drosophila damage and pupa (arrow). Scale bar = 1/8 inch. (C) Mouth hooks characteristic of Drosophila larvae (arrow). Scale bar = 1/32 inch.

The damage we describe for navel orangeworm above (Figure 3A) is actually characteristic of lepidopteran larvae in general rather than navel orangeworm specifically. We presumed that this was caused by navel orangeworm because, in 2002 and 2003, we recovered few if any larvae of raisin moth, the only other lepidopteran we found in harvest samples of figs. In 2004 we more quantitatively assigned lepidopteran damage to one of three sub-categories: known navel orangeworm or known raisin moth if an identifiable insect was found in the damaged figs, or unknown lepidopteran if the fig was categorized based only on damage. The results are presented in the next section.

Trends in Insect Damage

Sites and sampling. This study was conducted at 6 field sites, the first in extreme southern Merced County and the rest in Madera County, California. This area currently represents the majority of fig production in California. Site 1 was located northeast of the corner of Buchanan Hollow Road and White Rock Road; site 2 was on Avenue 27.5 near Road 24; site 3 was northeast of the corner of Road 27 and Country Club Drive; site 4 was near Avenue 12 and Road 32; site 5 was near Avenue 18 and Road 16; and site 6 was near Avenue 20 and Road 31. Sites 1, 2, and 3 were large contiguous plantings (1 to 2 square miles) containing several fig varieties. Sites 4 and 5 were plantings of Calimyrna figs only; site 4 consisted of 140 acres and site 5 comprised 320 acres. Site 6 contained 0.5-mile wide × 2 mile long strips of Calimyrna figs interspersed between equal dimensioned strips of pistachios. Pistachios, known to have high abundance of navel orangeworm, were also adjacent to sites 3 and 4. Grapes, known to have high abundance of nitidulid beetles, were adjacent to site 4.
In commercial production, figs are commonly knocked to the ground to complete drying and facilitate harvest. Fifty Calimyrna figs were collected per sample from the ground from each site at three times each year corresponding approximately with the producers' first three harvests; typically August 20, August 30, and September 5. These samples were taken from studies of the effects of mating disruption and spinosad treatments against navel orangeworm and mass trapping treatments against nitidulid beetles. In all cases there was no significant effect due to these treatments. Plot size and sampling intensity varied between these experiments, but plots were generally 20 to 40 acres and an average of 1 sample per acre was taken (e.g., ~210 feet between samples). Total numbers of figs samples were: 6592, 5482, and 1780 for sites 1, 2, and 3 in 2002; 7196, 4850, 4195, and 9001 for sites 1 to 4 in 2003; and 2400, 2403, 2699, 4802, and 3300 for sites 1 and 3 to 6 in 2004. Fig samples were held at -30°C for ~60 days prior to evaluation by Fresno-based inspectors of DFA of California (Sacramento, CA), a private corporation with sole authority for grading figs under California law. Figs were evaluated by market order criteria, as described in detail elsewhere (2). Figs evaluated as insect infested were returned to us, and we evaluated the insect pest(s) most likely responsible for the damage. For each fig, insect infestation damage was recorded as resulting from one of five mutually exclusive causes: (i) figs damaged solely by nitidulid beetles; (ii) figs damaged solely by navel orangeworm; (iii) figs damaged solely by *Drosophila* spp.; (iv) figs damaged due to multiple infestation involving nitidulid beetles, navel orangeworm, and/or *Drosophila* spp.; and (v) figs damaged by or contaminated by the presence of

insects other than nitidulids, navel orangeworm, or *Drosophila*.

Proportion of damage caused by pest species. To examine the relative importance of these five pest categories, harvests and samples were pooled and the proportion of figs damaged by each pest category was summarized for each site and year (Figure 5). Of 54,700 figs sampled over the three years, 4,734 (or 8.6%) were infested with insects. Of those infested, 53% were infested by nitidulid beetles, 32% by navel orangeworm, and an additional 7% were infested by a combination of these two pests and *Drosophila*, which was much less abundant. Thus nitidulid beetles and navel orangeworm were responsible for ~90% of insect damage to figs in this study.

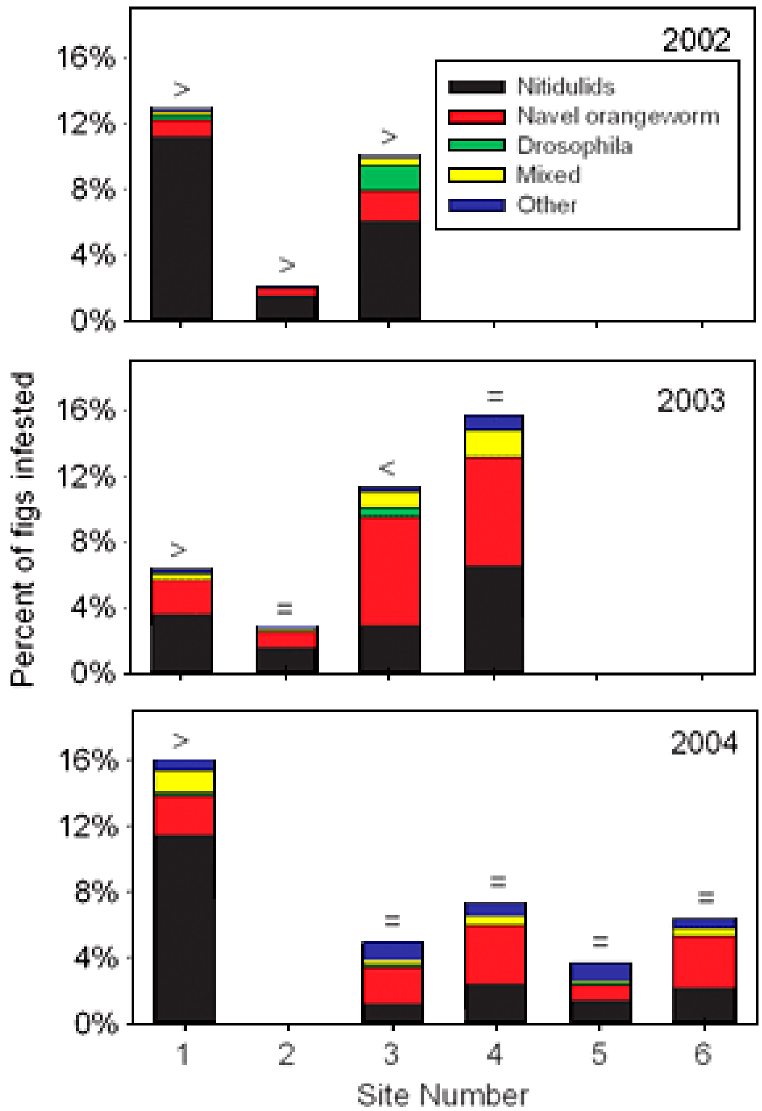

Figure 5. Total insect damage to dried figs at various sites over 3 years, and proportion of that damage caused by each pest category. The sign over each bar indicates whether the number of figs damaged by nitidulid beetles and navel orangeworm are significantly different (Fisher's Exact Test, $P < 0.05$) for that location and year. Signs: =, not significantly different; >, significantly more nitidulids than navel orangeworm; <, significantly fewer nitidulids than navel orangeworm.

To examine relative economic importance of nitidulid beetles and navel orangeworm, Fisher's Exact Test (PROC FREQ with EXACT option, SAS Institute, Inc., Cary, NC) was used to examine whether the number of figs infested by nitidulids and navel orangeworm at each site was significantly different ($P < 0.05$). In 2002 there were significantly more nitidulids than navel orangeworm at all three sites, but infestation by nitidulids and navel orangeworm was generally similar in 2003 and 2004 (Figure 5).

Since the damage characteristics used to categorize figs as navel orangeworm infested could also have been caused by raisin moth, in 2004 we characterized figs with lepidopteran damage as one of three subcategories as previously described. In 2004, 418 figs (2.7% of those sampled) were damaged by Lepidoptera. Of those, 63% were navel orangeworm infested, 4% were damaged by raisin moth, and 33% of these samples were damaged by Lepidoptera, species unknown. Of the 17 figs infested by raisin moth in 2004, 11 were recovered from one harvest at one site. Presuming that the lepidopteran damage in the figs in which we could determine species was representative of those in which we could not, raisin moth would have been responsible for infestation of 1% of all figs sampled at that site and harvest (compared to 5% for navel orangeworm), and for < 0.15% of infestation at the other 14 site-harvests for 2004. Ants were responsible for the majority of damage in the "other insects" category. In 2004 ant damage comprised 54 to 86% of the damage in this category, and ranged from 0.3 to 1% of all figs sampled among the sites and harvests (Figure 5).

Change in percent infestation over the harvest season. In order to examine whether navel orangeworm and nitidulid infestation increase over the season, we examined data for three years for sites 1 and 3 at three harvest dates. We measured the proportion of figs in each 50-fig sample infested by nitidulids, and the proportion infested by navel orangeworm. Figs which had damage from both nitidulids and navel orangeworm were included in both counts and analyses. Proportions were transformed as the arcsine of the square root of the proportion and examined using a 3-way factorial ANOVA (The SAS System, PROC GLM) with year, site, and harvest as main effects. We sampled equivalent numbers of samples (from 12 to 44 samples of 50 figs each) at each harvest date within site and year, for a total of 8,372, 11,391 and 4,803 figs observed in 2002, 2003, and 2004, respectively.

On average, both key insect pests showed higher damage at later versus earlier harvest dates. All main effects of year, site, and harvest date were significant ($P < 0.05$) in the analyses of infestation both by nitidulids and by navel orangeworm. All 2-way interactions between these factors were also significant for both pests, but the three-way interaction was not significant for either pest, so this term was omitted from the final analysis. Post-tests using the Tukey-Kramer correction for multiple comparisons (LSMEANS with Tukey option) showed that, across both sites and all three years, the number of figs infested with navel orangeworm was significantly greater in harvest 2 than in harvest 1 ($P < 0.05$), and the proportions of figs infested with navel orangeworm and with nitidulids in harvest 3 were both significantly greater than the proportions for the first two harvests. There was much variability within individual sites for particular years, as indicated by the significant interaction terms. At individual locations, infestation in some cases remained steady or dropped with subsequent harvests (Figure 6). Thus, while there is a general trend of increasing infestation with subsequent harvests, the level of infestation in a harvest at a particular site is a poor predictor of infestation in subsequent harvests.

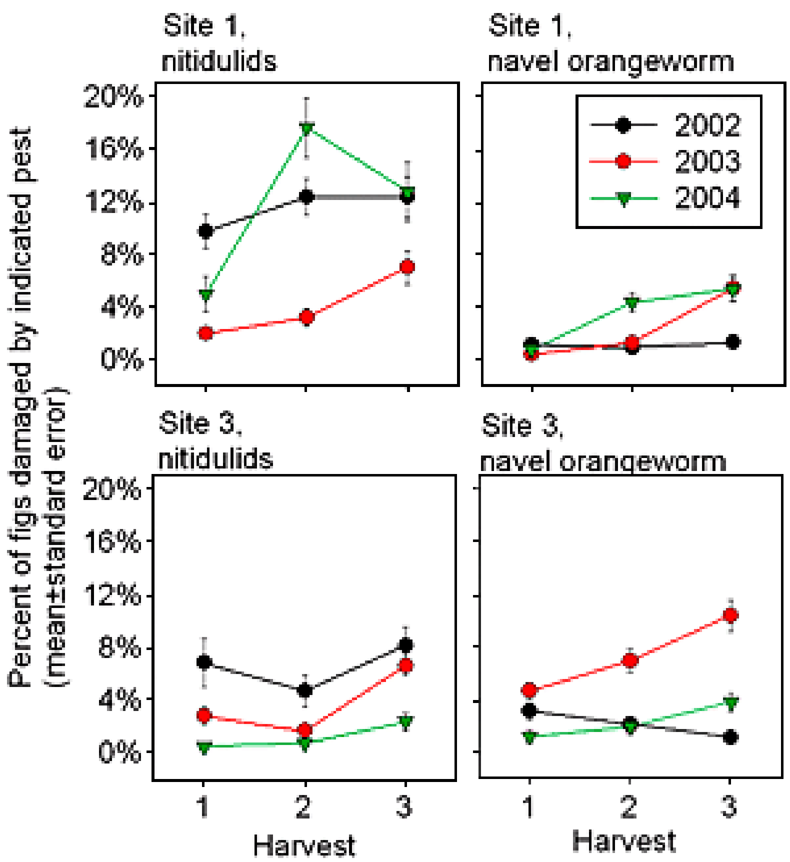

Figure 6. Percentage of figs infested by nitidulids and navel orangeworm over the harvest season at sites 1 and 3, 2002-2004. The vertical bars indicate standard error of the mean. Harvest dates correspond to approximately August 20, August 30, and September 5. While there is a significant trend of increasing infestation by both pests with subsequent harvests, this is highly variable and not always evident at individual locations within a single year.

Conclusions

This study indicates that the navel orangeworm and nitidulid beetles are the primary pests for dried figs and are, together, responsible for the majority of producer losses to insects. While nitidulid beetles caused more damage than navel orangeworm in this study, the data presented here also demonstrates much variability between sites and years in proportion of damage caused by these two pests. Among the sites examined here navel orangeworm was a problem primarily in sites in relatively close proximity to alternative hosts, whereas nitidulid beetle infestation sometimes occurred in high proportion in sites isolated from alternative hosts for that pest (e.g., sites 1, 2, and 3). The greatest practical suggestion from this work is that producers should examine insect infested figs from their sorting lines over several years, using the characters described here, to determine which of these two primary pests tends to cause more damage at their location, and then take these data into account in planning pest management tactics. These data also support the current practice of harvesting figs as early as practical.

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