Role of Natural Enemies

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This research focused on two potential secondary almond pests, the obliquebanded and the leaffooted bug, that have recently increased in densities and have been reported to cause economic damage in some almond orchards. Both pests attack a variety of crops, including pistachios. The proposed work combined funds from pistachio and almonds commodities to investigate pest and natural enemy biologies.

OBLR. The obliquebanded leafroller (OBLR), *Choristoneura rosaceana*, is a moth pest of almonds, pistachio and other crops (e.g., apple, cherry, prune, peach) that has, in some Central Valley orchards, recently moved from a minor to a primary pest. Unlike some of the other moth pests, OBLR larvae can feed on both almond leaves and nuts. In pistachio, the primary damage resulting from OBLR feeding is not to the crop but to the leaves! In some infested orchards, OBLR population densities have been observed at such high levels that extensive defoliation resulted in yield loss and crop damage. The exact causes for these outbreaks are not known, but their frequency and intensity appears to have increased over the past five years (Brent Holtz, Gary Weinberger, personnel observations).

Natural enemies are often cited as one of the primary factors in OBLR regulation. Our survey in 2000 shows OBLR attacked by four parasitic wasps (*Macrocentrus* nr. sp. *iridescens*, *Spilochalcis* sp., *Scambus* sp., and a eulophid species), at least one parasitic fly (a tachinid). In the literature, there are many more parasitoids listed and there is also a wide range of generalist predators, such as green lacewings, that prey on moth larvae. Along with regulation by natural enemies, there is the very good possibility that temperature and humidity in the orchard and at alternate host sites help dictate seasonal OBLR egg and larval densities.

In 2001, we compared OBLR and natural enemy population densities in orchards reported to have low and high pest status. Some of the more basic biological information for these pests is unknown. For example, "What is the relationship of pheromone trap catches to orchard population? Are these moths a transient (from one of its many alternate host plants) or resident (an established population in the orchard) pest?" To study, three almond blocks with reported OBLR populations were sampled (Madera, CA). At each sample block, no insecticides directed at OBLR or navel orangeworm (NOW) were planned. Throughout the season, adult OBLR were monitored with pheromone traps (three per field). Periodically, foliage was searched for OBLR eggs and larvae. The presence of generalist predators were determined by taking 50 "beat" samples every other week in each sampled orchard. Insects collected were taken to the laboratory for identification and these samples will be compared to data collected from pistachio orchards without OBLR damage.

One of three fields was treated for NOW and dropped from the survey. Results in the other fields were quite clear. Pheromone trap catches showed high adult catches of OBLR at each site located near infested pistachio. Seasonal abundance and phenology (the number of flights and their timing) were quite similar to trap catches in pistachio. However, a visual search of almond foliage found very few OBLR strikes on almonds. Foliage found with (possible) OBLR larvae were typically leaves webbed together or against almond nuts. We found no almond nuts positively infested with OBLR. Note that the study began in May – which may be important.

We conclude that mid and late-season high OBLR counts in pheromone traps are a result of migrating OBLR adults. Furthermore, while OBLR may lay egg masses on almond trees, the mid and late-season almond foliage was not a preferred host in the orchards sampled and that OBLR densities and damage to almond were not significant. We will conclude this study this winter and spring by looking at early season damage. While our studies began in May, we have been told by colleagues that overwintering OBLR will enter green nuts and hollow out nuts –leaving little outside webbing for detection. Cage trials of OBLR larvae will help to isolate the periods of feeding damage.

Leaffooted Bug. Many Hemiptera, or true bugs, are capable of causing damage directly to almond or pistachio nut. Most of these pests are present early in season, especially the “small” bugs, includes several species of Miridae and Rhopalidae, such as lygus (*Lygus hesperus*). These small bugs may be abundant early in the season; however, they cease to cause damage after the shell begins to harden. The second group is composed of species of Pentatomidae (the stink bugs) and Coreidae (leaffooted bugs). These "big bugs" can cause the same damage as their smaller relatives during the first half of the season. However, later in the season (from shell-hardening until harvest) the big bugs may be able to puncture the nut-meat through the shell, causing damage and possibly transmitting fungal pathogens. Currently, control measures rely singularly upon insecticides, applied soon after hemipterans are discovered, and there are no true economic injury levels identified for these pests.

We investigated the leaffooted bug, *Leptoglossus clypealis*, because its densities dramatically increased in the 1999 and 2000 seasons in many crops (including almonds and pistachios). More research is needed to better understand hemipteran biology, ecology and pest status, including (1) overwintering sites, (2) migration and dispersal behaviors, (3) host plant relationships (e.g., alternate hosts), and (4) almond nut damage and (5) biological control.

We utilized small cages to collect information on leaffooted bug biology and feeding damage to the almond. We caged bugs on nuts to determine damage levels throughout the season. To accomplish this work, when flowering begins, we isolated almond nuts to provide insect-free sites. Nymph and adult hemipterans (separate cages for each development stage tested) were placed into the field cages at various times throughout the season (insectary colonies of leaffooted bug provided tested insects). The insects were left to feed on the almond nuts for 7 days and then removed from the cages. During the "feeding" trial, points of insect damage to nuts (punctures) were marked and crop damage later determined. Throughout the study, a penetrometer was used on selected nuts to determine fruit firmness. Nuts were collected from these cages at harvest and dissected for damage.

These cage trials were conducted at the Kearney Agricultural Center, with new cages set up every two weeks to determine when leaffooted bug injury is most important to almonds. In commercial orchards we also tested five different cultivars (Butte, Carmel, Non-pareil, Fritz, and Mission) to determine if leaffooted bug damage varies among cultivars because of shell hardness. These "cultivar" trials were conducted at early (April), mid (June) and late (July) season periods. For both the feeding and cultivar tests, we used 7- 10 replicates for trial (e.g., tested period, cultivar or bug development stage).

Results show that leaffooted bugs can cause significant damage to almond nuts early in the season. In April and May trials, damaged nuts typically shriveled and fell from the almond. There is probably little or no compensation by the tree for these damaged and dropped nuts – which would be measured as crop loss. Later in the season, damaged nuts showed external damage to puncture (gummosis extruding from the puncture wound). However, dissection of nuts indicates that by June, leaffooted bugs feed only on the outer epicarp and did not, in most cases, puncture through to the nut meat. These data are still being analyzed, but initial summary indicates that leaffooted bug is an important early-season pest.

Data on leaffooted bug development and phenology are still being analyzed. Similarly data on cultivar differences have yet to be analyzed. However, if leaffooted bug is primarily an early-season pest on Butte cultivar, it stands to reason that even the softer shelled cultivars would have some resistance to damage later in the season. We also note that in some varieties (especially) a physiological trauma to the nut forces fluid out through the epicarp and can look very similar to insect feeding damage. Our observations suggest that late season gummosis tubes from this physiological damage (which was often common) could be mistaken for insect damage.

Natural regulation of leaffooted bug may provide the needed late-season control. In commercial blocks we searched for leaffooted bug egg masses. As in pistachio, a small egg parasitoid (*Gryon pennsylvanicum*) can dramatically suppress leaffooted bug densities.

In each sampled orchard, nuts with lesions typical of hemipteran feeding were collected from otherwise healthy clusters. These nuts were surface sterilized in the laboratory, and then a small sample was excised from the lesion with a heat-sterilized scalpel. Each piece will be cultured and incubated and the resulting fungal pathogens were identified. Dr. Themis Michalaides identified *Alternaria alt*ernate as the most common fungus present; other fungi included: *Phomopsis, Cladospoium, Fusarium, Penicilium, Aspergillus, Paecilomycos, and Ulocladium*.