Role of Natural Enemies in Regulation of the Leafroller and Leaffooted Bug

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This research focused on two potential secondary almond pests, the obliquebanded leafroller 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. Our work combined funds from the Almond Board of California and the California Pistachio Commission to investigate pest and natural enemy biologies.

OBLR. The obliquebanded leafroller (OBLR), *Choristoneura rosaceana*, is a moth pest of almond, 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 pistachio 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). OBLR's pest status in almonds has not been clear: very high counts of male OBLR can be found in pheromone traps, but it is very difficult to search the almond tree and find OBLR larvae in the nuts or leaves. In contrast, OBLR larvae and their distinctive "folding" or "webbing" of infested leaves are quite obvious in pistachio orchards throughout the season.

Natural enemies are often cited as one of the primary factors in OBLR regulation. We surveyed for OBLR natural enemies in almonds and pistachios from 2000-2002. Common parasitoids collected included *Trichogramma pretiosum*, which parasitized 60-80% of the egg clusters in August and September collections, *Macrocentrus iridescens* (Hym. Braconidae) and *Actia* sp. (Dip. Tachinidae), which parasitized 40-80% of OBLR larvae in August and September samples. Rarely collected parasitoids included *Goniozus* sp. (Hym. Bethylidae), *Spilochalcis* sp., an unidentified eulophid species, an unidentified tachinid species, and *Scambus* sp. (Hym. Braconidae), all of which attack OBLR larvae. Listed in the literature are many more parasitoids attacking OBLR, in particular there are braconid parasitoids (*Bracon* species) that attacks later development stage OBLR. This past year we found one of these species, *Bracon* nr. sp. *cushmani*, to be quite common and effective at reducing OBLR densities. There is also a wide range of generalist predators, such as green lacewings, that prey on moth larvae.

From 2001-2003, we have compared OBLR and natural enemy population densities in almond and pistachio orchards reported to have low and high pest status in order to answer some of the basic biological information for these pests. To answer some of these questions, three almond blocks with reported OBLR populations were sampled (near 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. For example, we found that OBLR can have three generations In Central Valley pistachio orchards, while they typically have only two generations in almonds, pears and apples. The additional generation may contribute to the high OBLR densities seen in pistachios but avoided in neighboring almonds. Trap counts and field examination of almonds suggest that, earlier in the season OBLR, has a higher density and can cause slight damage (<5%) to the developing nuts. This is an opposite pattern from that found in pistachios, where the OBLR densities and damage increase in June and July. We found no almond nuts infested with OBLR at harvest, even though pheromone traps show significant densities of OBLR in the almond orchards sampled.

In 2003, we also set up cage trials throughout the season to determine the potential damage by OBLR feeding on the almond in various stages of nut development. In March, before flowering began, we isolated almond buds to provide insect-free sites. OBLR larvae were placed into the cages at various periods of the almond development, from early bug development, to flowering, to formation of the almond nut. We continued to add OBLR to clean cages throughout the season, with the OBLR developmental stages used matching the naturally occurring OBLR stages in the field. During each trial we determined external feeding damage to leaves and nuts and we dissected all nuts at harvest to determine internal damage. These data have not yet been analyzed, however, observations during the trial suggests that OBLR prefers to feed on leaves throughout the season. We did not find many OBLR feeding on the buds; however, in our trials, March temperatures were cold and most releases OBLR second instars died. Later in the season (March-April), feeding by OBLR larvae caused some nut drop. This occurred during a period of high natural nut drop, and we collected data to determine if nut drop in OBLR cages was significantly higher than normal nut drop or if the almond compensated for the early-season crop loss. At harvest-time, we collected all nuts from cage trials to determine season-long damage ratings. These nuts are currently being processed for OBLR damage, but field observations suggest similar result as found in 2002 trials where early season nut damage was primarily from dropped nuts (4%) and rarely with internal nut damage (0.1%). In mid season trials there was some external feeding damage (2.3%), fewer dropped nuts (0.15%), and no internal damage. In late season trials there was minor external feeding (when leaves were webbed against the nut) with no dropped nuts and no internal damage.

We conclude that early season presence of OBLR can result in some nut damage – primarily through dropped nuts. However, it is difficult to separate the importance of these dropped nuts from the natural drop that occurred in all our March – April trials.

We found that mid and late-season feeding of OBLR in almonds is not important and that high OBLR counts in pheromone traps may represent adults drawn in from other crops (e.g., pistachio). 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 OBLR densities and damage to almond were not significant.

In 2003, we concluded studies on *Macrocentrus iridescens* biology and field manipulation. This braconid parasitoid has been the most common OBLR natural enemy in pistachios, but has not been recovered in almonds. Laboratory studies showed this parasitoid prefers to attack first and second instar OBLR, but the adult parasitoids do not emerge until the OBLR has developed to the fifth instar. It is an internal, polyembryonic parasitoid, meaning that one egg will split numerous times during development to produce broods with about 30 *Macrocentrus iridescens* from one parasitized OBLR. The parasitoid has low and high temperature thresholds of 9 and 35°C, respectively, with an egg to adult temperature requirement of 730 day-degrees. In comparison, other researchers found that OBLR has low and high temperature thresholds of 10 and 32°C, respectively, with an egg to adult temperature requirement of 700 day-degrees. Field comparison of *Macrocentrus iridescens* and OBLR field development shows that the parasitoid will have only one generation to each OBLR generation.

Each winter, densities of *Trichogramma pretiosum* and *Macrocentrus iridescens* drop dramatically and parasitism levels in monitored pistachio fields drop from 30-80% in August to <10% the following spring. For this reason we tested augmentation of both species in pistachio and almond orchards. *Trichogramma pretiosum* was produced by a commercial insectary and released in July, to match the natural egg-laying period of OBLR, at a rate of 500,000 per acre. *Macrocentrus iridescens* was produced in our insectary and released in April and March, to match the natural period of spring activity of overwintered first and second instar OBLR larvae, at a rate of 1000 to 1500 per acre. While data are not yet thoroughly analyzed, observations of OBLR and parasitism densities in release and control plots showed no increase in parasitism levels. We conclude that neither *Trichogramma pretiosum* and *Macrocentrus iridescens* are the best candidates for an augmentation program.

Leaffooted Bug. Many Hemiptera, or true bugs, are capable of causing damage directly to the 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.

In 2003, leaffooted and stinkbug densities rebounded from low levels recorded in 2002. We caged bugs on nuts to determine damage levels – with the cages established in a similar manner as described for the OBLR study. Adult leaffooted bugs were placed into the field cages at various times throughout the season. The insects were left to feed on the almond nuts for 7 days and then removed from the cages. This means that each branch had severe exposure to a healthy, leaffooted bug – thereby intensifying damage. During the "feeding" trial, points of insect damage to nuts (punctures) were marked and crop damage later determined. These cage trials were conducted at the Kearney Agricultural Center and commercial orchards with five different cultivars (Butte, Carmel, Nonpareil, Fritz, and Mission) tested 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 each trial (e.g., tested period, cultivar or bug development stage). Nuts were collected from these cages at harvest and dissected for damage. Results from these studies are still being process. Observations during the study suggest that leaffooted bugs and stinkbugs can be important early-season pests. In mid- and late-season trials, the bugs can penetrate the outer epicarp, resulting in a puncture wound, but do not easily puncture through to the shell to the nut meat. The cultivar that appeared most susceptible is Fritz, with most other cultivars showing very little internal damage to the nut meat. Here, we have not taken into account dropped nuts and a more thorough analysis will compare the natural drop in control and treatment cages to the damaged and dropped nuts.