Navel Orangeworm (*Amyelois transitella* (Walker)) and Obliquebanded Leafroller (*Choristoneura rosaceana*) (Harris) as Pests of Pistachio

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Pistachio production in California has increased dramatically during the past 20 years. Pest problems associated with pistachio have increased along with production. Initially thought to be pest free, a variety of arthropods have been found associated with pistachio that damage the crop. Two key lepidopteran pests include navel orangeworm (NOW), *Amyelois transitella* (Walker), and obliquebanded leafroller (OBLR) *Choristoneua rosaeceanna* (Harris). Navel orangeworm infests nuts once they have matured while OBLR primarily results in leaf defoliation and damage to nut clusters prior to maturity.

NAVEL ORANGEWORM

The primary pest of pistachio is NOW. Nut infestation results in reduced yield, greater processing costs, and association with aflatoxin contamination. It was first identified in 1915 as *Myelois venipars* from a male collected in Oaxaca, Mexico, and a female from Hermosillo, Mexico. It was not found in the United States until October 4, 1920 from light trap collections near Tempe, Arizona (Wade, 1961). In 1942 NOW was recorded in Orange County and quickly spread throughout southern California. By 1949 NOW was collected in northern California in Tehama County where it was primarily a pest of walnut and almond. It was detected infesting pistachio in the mid 1960s, and can now be found infesting pistachio throughout all production regions in California.

Male and female moths are similar in appearance with the male being smaller. They are predominantly gray in color with narrow, wavy, black bands across the front pair of wings (Plate 24A). The wing expanse of females has been measured over 1 inch with the length of the body up to 1/2 inch (Wade, 1961). Moths are characterized by the pointed palps at the front of the head. Females lay eggs that are creamy white, reticulated, flat and approximately the size of a pinhead (0.5 to 1 mm). Approximately 50 eggs are produced per female and maximum oviposition occurs by moths 2 to 8 days in age (Goodwin and Madsen, 1964). As the egg matures it becomes bright red and eventually a small black worm can be seen inside. Larvae hatch in as little as three days during the summer. When newly hatched, larvae are reddish orange and quite small. After the first molt, they become cream colored but the color of their food can influence body coloration (Plate 24B). Larvae go through five or six growth stages and at maturity may reach 3/4 inch in length. These larger larvae have sclerotized dark areas that form a half circle on the upper portion of each side of the middle thoracic section (above the middle pair of true legs). These sclerotized areas are about the size of a pinhead. More than one larva can be found infesting a nut because NOW are not cannibalistic.

Overwintering occurs as a partially grown larva in the crop host remaining in the field. Larvae survive on food in trees or on the ground. Food hosts in which NOW are commonly found include pistachio, almond, walnut, pecan, fig, pomegranate, apple, orange, grapefruit, lemon, carob, date, peach, apricot, pear, plum and loquat (Wade, 1961). Navel orangeworm cannot survive the winter without a host. This is a key to managing the pest.

Beginning as early as late March, NOW moths emerge from pupation and begin oviposition on unharvested nuts remaining in the tree. If nuts remain undestroyed on the ground and are infested, moths can continue to develop on these grounded nuts throughout the season. In pistachio, grounded nuts are quite numerous and can serve as the major source of infestation of new crop nuts in July. It is extremely important that this source of NOW be destroyed.

Navel orangeworm egg traps (Rice, 1976) that contain almond meal and 3 to 10% (by weight) almond oil are the most effective method for monitoring NOW during the season. They can be used to identify the occurrence of different generations of NOW. Figure 24a presents the egg laying trend in pistachio utilizing the NOW egg traps. Development of each generation, from first eggs of one generation to the first eggs of the next generation averages approximately 1050 degree days (dd) (Fahrenheit scale). Four generations per year are common. The degree day calculations are based on a lower developmental threshold of 55 °F and an upper developmental threshold of 94 °F (Engle and Barnes, 1983; Seaman and Barnes, 1984; Zalom et al., 2000). Calculation can be done utilizing the degree day methods in the UCIPM web page (http://www.ipm.ucdavis.edu).

Work is currently underway to improve monitoring capabilities by developing a pheromone for NOW. At present a sex pheromone has been identified, but has not been refined for monitoring male moths. It is expected that the NOW pheromone will be used as an effective monitoring tool in the near future.

In pistachio, NOW must go through two generations on the previous seasons unharvested nuts before the new crop is susceptible to attack. This can be done on nuts in the tree or infested nuts remaining on the ground. Larvae do not commonly penetrate new crop nuts until the husk begins to separate and the shell splits. Occasionally, entrance can occur through the stem end of nuts. Navel orangeworm is not attracted to nuts until the husk begins to tear (Beede et al., 1984; 1985). However, studies have shown that small, deformed nuts that split in mid July can serve as a host for young larvae.

NOW larvae damage almond kernels during the last two generations in August and September. Figure 24b shows the relationship between the beginning of the third generation

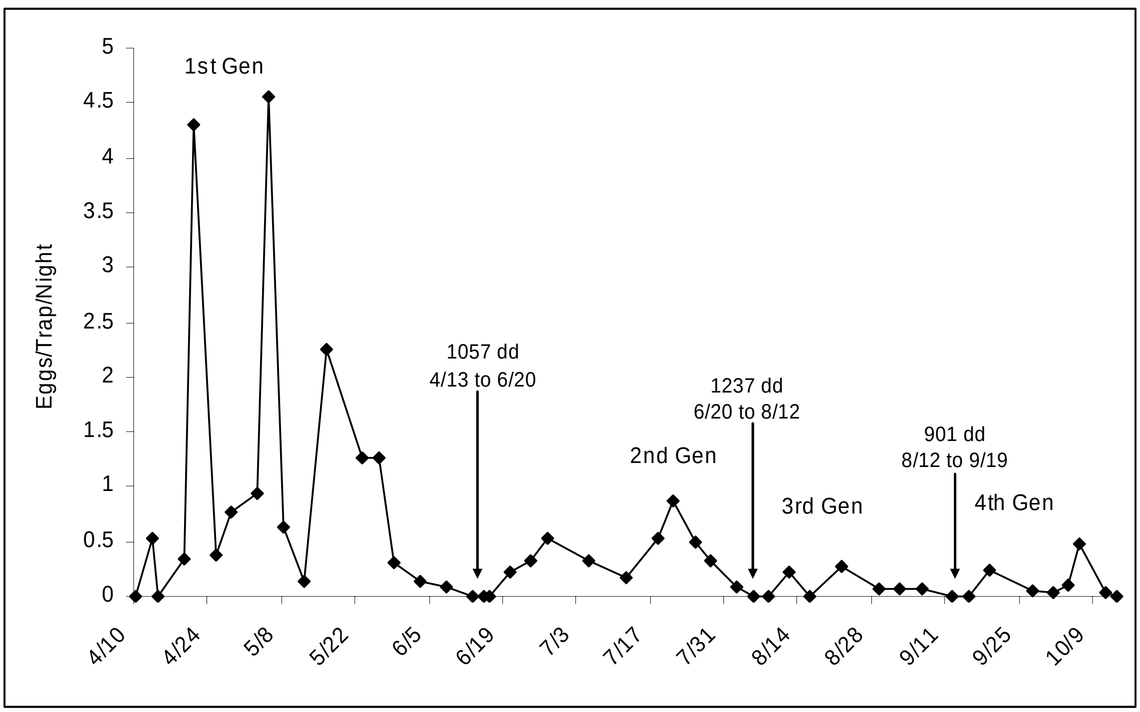

Figure 24a. Seasonal egg laying activity of navel orangeworm in pistachio, Dudley Ridge, CA.

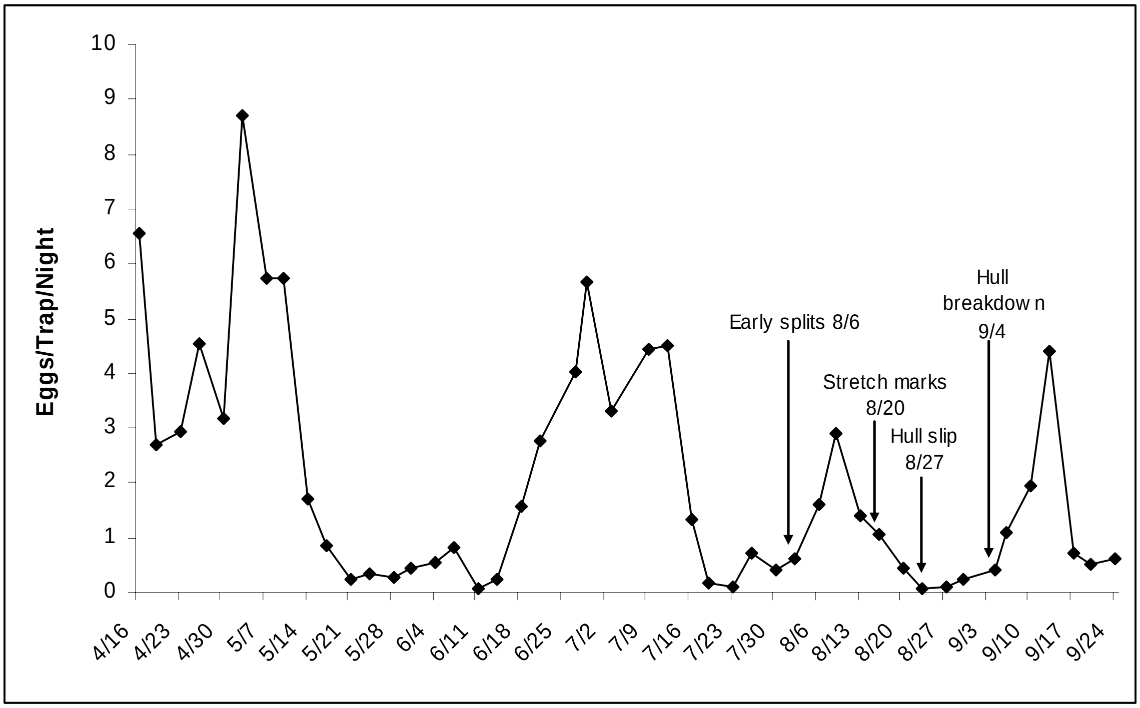

Figure 24b. Relationship between navel orangeworm egg laying and pistachio nut susceptibility, Dudley Ridge, CA.

egg deposition and the development of nut susceptibility. Management of NOW is dependent on breaking the host cycle by removing the previous seasons unharvested nuts during the winter and destroying them. This successful technique has been demonstrated repeatedly in almond (Caltagironi et al., 1968; Zalom et al., 1984). This approach is also recommended in pistachio.

Other NOW management techniques include harvesting prior to development of the fourth generation (early harvest), biological control and insecticide control. Due to limited nut processing capabilities, early harvest is not always possible. To overcome this problem pistachio farmers should schedule harvest of those orchards that have not received winter sanitation or that have a history of high NOW reject first.

Biological management of NOW can occur but is not a reliable method of control in pistachio. Two parasitoids are commonly found. The most widespread is *Goniozus legneri* Gordh, a wasp in the family bethelidae. The female wasp stings, paralyzes, and lays an egg on the NOW larva. This egg hatches into a wasp larva that feeds on and kills the immature NOW. It is commercially produced for sale as a biological control agent. A second parasitoid in the family encyrtidae, *Copidosoma plethorica* Caltagironi, is not commercially produced, but is commonly found where orchards are unsprayed. Although not studied in pistachio, naturally occurring populations of these two parasitoids have not provided consistent control of NOW in almonds (Strand, 2002). The common predators include various species of lacewings, spiders, and the plant bug *Phytocoris spp*. *Phytocoris* has been demonstrated to cause epicarp lesion of pistachio (see Chapter 20), but its value as a NOW predator has not been investigated. There are other predators, but they provide minimal population reduction.

The severity of NOW infestation can also be influenced by other arthropod pests such as citrus flat mite, *Brevipalpus lewisi* McGregor (see chapter 20) and the mealybug *Ferrisia gilli* Gullen (See chapter 25). Both pests feed on developing nut clusters and cause individual nuts to dry on the tree. These dried nuts are not removed during the normal harvesting operation and remain on the tree as a wintering host for NOW, thereby increasing the within orchard population.

Insecticides have played a major role in the management of NOW in late harvested pistachio orchards. Insecticide treatments of organophosphate, carbamate, and pyrethroid insecticides have provided up to 75% control when compared to untreated nuts. Timing of application has been critical in achieving optimum control. Insecticides applied at 400 to 500 degree days (55 °F base and 94 °F upper thresholds) after third generation egg laying begins has been the optimum treatment timing (Bentley and Surber, 1985). Table 1 gives the relative efficacy of timed insecticide trials aimed at NOW. Single applications are generally quite effective in reducing infestation to acceptable levels. Recent research is focusing on insecticide timing for the very early split shells occurring in mid July as a critical period for control. It may be possible to treat after second generation egg laying begins with softer materials less likely to trigger secondary pest outbreaks. The newly developed insecticide methoxyfenozide, an insect growth regulator, is currently being widely used as a substitute for the older materials. Other new, effective and environmentally safe insecticides are being developed and examined.

Although insecticide control is an important aspect in the management of NOW, overuse and poor timing of organophosphates, carbamates and pyrethroids can cause other problems. In particular, webspinning spider mite outbreaks often follow the use of these sprays. This is most commonly seen on the west side of the San Joaquin Valley. The impact of repeated sprays on important predators of NOW have not been well documented.

Table 1. Effects of timed spray applications on navel orangeworm infestation in pistachios, Kern County, CA.

Spray timing[1,2]	% Infested nuts[3] 1984	% Infested nuts[3] 1985	% Hullsplit per 500 nut sample 1984	% Hullsplit per 500 nut sample 1985
100° D	---	1.0 bc	---	.20
200° D	---	.4 a	---	.60
300° D	.20 ab	.6 ab	.20	2.20
400° D	.10 a	.35 a	1.50	2.80
500° D	1.05 c	.30 a	4.75	2.80
600° D	0.80 bc	.85 abc	4.75	4.40
700° D	0.60 abc	---	6.00	---
Check	1.05 c	1.35 c	---	---

1 In 1984 application made by ground with Meyer's pto. sprayer at 100 gpa and 100 psi at 2 mph (Permethrin applied at .2 lb a.i. per acre). In 1985 application made by ground with FMC pto sprayer at 450 gpa and 350 psi at 2 mph (permethrin applied at .26 lb a.i. per acre).

2 Base development threshold 55° F and upper threshold 94° F. Calculation started on first recording date of third generation eggs using single sine curve method with horizontal cutoff.

3 Percent infested nuts based on cracking 200 shell split nuts per replicate in 1983 (10 replicates/treatment) and 400 shell split nuts in 1985 (5 replicates/treatment). Those numbers followed by the same letter not significantly different at the 5% level using Duncan's Multiple Range Test

OBLIQUEBANDED LEAFROLLER

Obliquebanded leafroller (OBLR), *Choristoneura rosaceana* (Harris), is a native North American moth in the family tortricidae (Chapman and Lienk, 1971). The larvae are reported to feed on over 70 different host plants (Chapman and Lienk, 1971). These include crops such as apple, apricot, walnut, almond, cherry, pear, plum, prune and peach in the San Joaquin Valley as well as non-crop hosts such as Valley oak *Quercus lobata* Nee, wild plum *Prunus subcordata* Benth., choke cherry *Prunus virginiana* L., California buckeye *Asclepius speciosa* Torr., rose *Rosa spp*., and raspberry *Rubus leucodermis* Dougl. In California there was little record of damage by this pest until 1989 when it was found on apples in the San Joaquin Valley (Bentley and Viveros, 1989). Since then it has also been found on pistachios where feeding damage occurs directly on developing nut clusters and leaves. Leaf infestation can result in defoliation prior to nut maturity and harvest. The reason for the current rise of OBLR to such a prominent pest of pistachio is not known.

Obliquebanded leafroller winters within silken hibernacula on the tree as third instar larvae. Emergence from the hibernacula occurs in early March in the Bakersfield area and mid March from Fresno north. The worms are light green with a dark black thorax and head (Plate 24C). First emergence will actually occur prior to leafing out of pistachio. The easiest method of OBLR detection is the presence of tied leaves in the spring. In pistachio however, leaf tying is not as evident as in apples and cherries. Full-grown larvae will reach approximately 1 1/4 inch in length. When webbed leaves are disturbed or separated, the worms actively wiggle backwards and drop to the ground on a silken thread.

Pupation occurs in mid to late April and the first moth flight begins in late April and May. The first trapped moth of the season is the biological fix that is used to begin calculating degree-days in an effort to time insecticides. Moths are monitored with standard pheromone sticky traps that have a rubber pheromone cap baited with the western strain OBLR pheromone. The moths are large, approximately 5/8 inch long. They are bell shaped with two colors predominating, a background fawn color, and a mahogany colored chevron the upper pair of wings (Plate 24D). They are easily confused with a much smaller species called the garden tortrix, *Clepsis peritana* (Clemens). The garden tortrix is attracted to the pheromone for the western strain of OBLR but is caught in March and April. The garden tortrix is 1/3 the size of OBLR. It does not feed on pistachio.

A single female OBLR moth can lay up to 900 eggs (Chapman and Lienk, 1971). Eggs are laid in groups of approximately 200. They are flat and overlap, much like fish scales, and are covered with a cement-like substance giving the cluster a light green coloration. Hatching occurs in approximately 12 days after being laid (Chapman and Lienk, 1971).

Obliquebanded leafroller basal development threshold is 43 °F (Onstad et al., 1985). In California, an arbitrary upper threshold has been set at 94 °F. Using these temperature limits, an average total of approximately 2000 degree days are required for a generation to develop. In northern California, as far south as Madera, there are generally two generations of the pest per year. South of Madera, three generations are common. Figure 24c presents the seasonal flight trend of OBLR in a Madera pistachio orchard.

Obliquebanded leafroller abundance is regulated by parasitoids and insecticides. A key parasitoid in California is *Macrocentrus irridescens* French, a polyembrionic braconid wasp about the size of a mosquito. It stings OBLR larvae in various stages of development and multiple wasp larvae develop within the host. It has been recovered throughout the San Joaquin Valley. There are others as well, but *Macrocentrus* is the most abundant in pistachio orchards.

A variety of insecticides provide effective control of OBLR. These range from *Bacillus thuringienses* (BT), methoxyfenozide (Intrepid®), spinosad (Success®), phosmet (Imidan®), esfenvalerate (Asana®), and Calcium polysulfide (lime sulfur). Timing the application of tebufenozide, spinosad, or phosmet has been investigated. Applications made at 1000 dd days (43 °F lower threshold

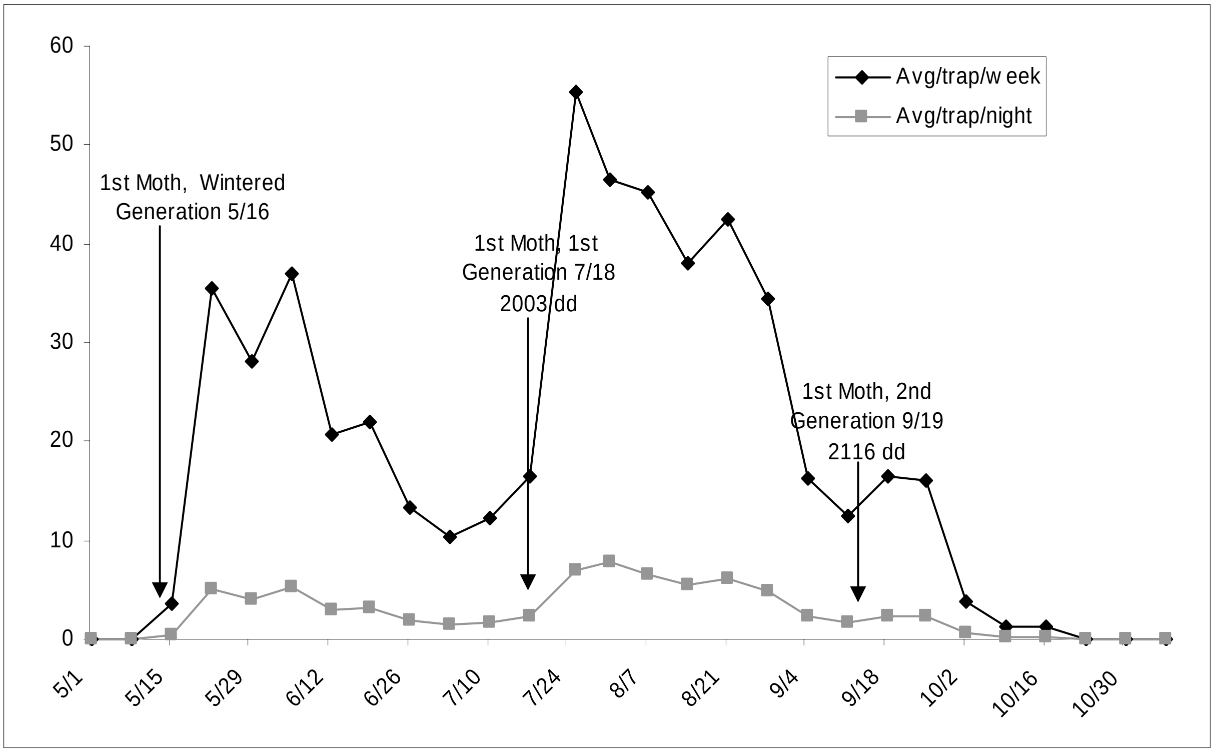

Figure 24c. Seasonal flight activity in obliquebanded leafroller in pistachio, Madera, CA.

and 94 °F upper threshold) after the first moth caught in the spring has resulted in optimum control of OBLR (Bentley et al., 2000; 2001; 2002).

Studies are currently being conducted on OBLR management in March and April, when first larvae are found infesting clusters. Non disruptive sprays of *Bacillus thuringiensis* and lime sulfur appear to work well in reducing the population of overwintering larvae as they emerge from diapause.

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