Orchard and plant management affect control of

Navel Orangeworm

on walnuts in northern California

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No effective spray program against the navel orangeworm—*Paramyelois transitella* (Walker)—has been perfected. Therefore, control is dependent on orchard and plant management because the insect, primarily a scavenger, is capable of attacking sound walnuts after the husks have cracked.

Potentially destructive populations of the navel orangeworm are able to maintain themselves in walnut groves throughout the year and the greatest threat from the insect seems to arise from conditions existing within the orchards.

No Diapause

The navel orangeworm has no diapause. Breeding continues until stopped by cold weather. During the late fall and winter, larvae in the nuts continue slow development. By late winter and early spring development is completed, mating occurs and a new generation is started. From spring through fall there are a number of overlapping broods. The larvae spin considerable webbing and from one to more than 25 individuals may develop in a single nut. Usually adults are not encountered in the field although under conditions of heavy infestations the adults may be seen during harvest time.

Because of the scavenger habits of the navel orangeworm, nuts infested by the codling moth furnish ideal breeding places that, probably, constitute the most important single source of navel orangeworm carry-over from one crop to the next. The navel orangeworm is unable to attack sound nuts until the husks begin to crack with maturity.

Food-Chain

The population of the navel orangeworm usually reaches its lowest level in early summer when breeding sources from the old crop are nearly dissipated. The food-chain that carries the insect over from one crop to the next is all but broken and walnuts infested by the codling moth fill in the gap. If a sizable codling moth infestation prevails, breeding of the navel orangeworm continues in the infested nuts. By harvest time a large population of the adult navel orangeworm may be present to attack sound nuts as the husks split.

Test Plots at Linden

In the experimental plots at Linden, the number of nuts attacked by the navel orangeworm in 1960 increased with a rise in the codling moth infestation—a relationship typical of all experimental investigations where the two insects were involved.

Walnut blight—probably less important than the codling moth—is a factor in the navel orangeworm problem. Developing walnuts are seriously infected by walnut blight and the totally destroyed nuts serve as a poor breeding source for the navel orangeworm. However, as in the 1959 season at Linden, when walnut blight is arrested before the nut is completely destroyed the husk and shell at the point of lesion often crack and expose the meat chamber. Such nuts, like those infested with the codling moth, are suitable breeding places for the navel orangeworm and serve to bridge the gap between the old and the new crops.

Due to a variety of factors other than codling moth and walnut blight, there are usually a number of walnuts that are blanks or contain shriveled or otherwise injured meats. The husks of these unsound walnuts tend to crack prematurely and thus are subject to attack by the navel orangeworm several weeks to a month before sound nuts are attacked. At harvest the cull nuts are frequently heavily infested.

Temperature and Moisture

The navel orangeworm thrives best at a moderately high temperature and under rather moist conditions. At harvest both temperature and moisture content of the nuts are favorable for the activity of the pest. However, there is evidence that the nuts are less subject to attack as they dry. When nuts on the ground are exposed to direct rays of the sun the temperature may rise to a level lethal to the navel orangeworm. Nuts in protected and moist locations are likely to be more heavily infested than those nuts in open and dry areas.

In 1959 and in 1960 the potential of the navel orangeworm as a pest prior to harvest appeared to be about equal. However, heavy rains occurred in 1959, and in 1960, dry conditions existed during and following harvest. Nuts left on the ground unharvested showed a considerably higher degree of infestation in 1959 than in 1960.

Dryness of the nuts may be one explanation for the navel orangeworm not breeding in storage to the same extent it does out-of-doors, although under favorable conditions troublesome popula-

Percent of Infested Walnuts in Harvested Crop in the 1960 Experimental Plots at Linden

Insecticide and pounds per acre	Date applied	Infested nuts		
		Codling moth	Navel orangeworm	
			Primary	Secondary[a]
Check	.....	14.0%	3.0%	3.7%
Sevin,[b] 50% W.P., 10	April 21 June 20	1.70	0.70	0.65
DDT, 50% W.P., 12	April 20	0.55	0.63	0.15
Guthion,[c] 25%, W.P., 6	April 22 June 21	0.32	0.48	0.10

[a] Navel orangeworm infesting nuts previously attacked by codling moth.
[b] 1-naphthyl N-methylcarbamate.
[c] 0,0-dimethyl S-4-oxo-1,2,3-benzotriazin-3(4H)-ylmethyl phosphorodithioate.

tions of the pest can develop during storage.

As fall advances, temperatures drop to a point where adult activity comes to an end and further infestation of nuts in the field ceases.

Evidence so far accumulated indicates that navel orangeworm larvae in the early instars are probably less resistant to cold than are those that are more mature. Such a situation might prove to be of considerable importance in pest populations during a severe winter.

The years, 1959 and 1960, were dry and mild. Unharvested nuts in the field did not deteriorate as rapidly as they would in a wet year which might have been an important factor in maintaining the navel orangeworm population at a threatening level.

Early Harvest

Prompt harvest of the walnut crop can reduce navel orangeworm infestation to an exceedingly low level even when a potentially destructive population is developing in the nonmarketable portion of the crop. A relatively small loss has been suffered in the experimental orchard at Linden when the sound nuts were harvested before the pest had an opportunity to infest them. When there was a delay in harvest, the sound nuts were heavily attacked.

The navel orangeworm enters sound nuts at the stem end, and when the closure is not complete there is no external evidence of their entry. As a result it is almost impossible to sort out infested nuts, and the presence of infestation can usually be detected only by cracking the nuts. However, as the pest approaches maturity it tends to eat through the soft tissue at the stem end or even directly through the hard shell. In the late stages of development, exit holes and associated webbing give evidence of infestation. Pupation of the pest may occur either within or outside of the infested walnut.

Rapid Drying

Dried nut meats are less favorable for navel orangeworm infestation than moist meats, and the rate of development is markedly retarded by rapid drying. In the case of first instar larvae, growth may be so reduced that the nuts can be delivered to the packing house and fumigated before injury progresses to a point where it can be detected in a crack test of the nuts.

Natural Enemies

Natural enemies may become important in checking walnut damage by the navel orangeworm. The parasitic wasps—*Microbracon hebetor* (Say), *Perisierola breviceps* Krombein, and *Mesostanus gracilis* Cr.—have been reported attacking the pest. Black hunter thrips—*Leptothrips mali* (Fitch)—have been reported as a possible predator on the eggs of the navel orangeworm.

In the present study the larvae of the clerid—*Cymatodera ovipennis* LeC.—have been found, on a number of occasions, attacking the larvae of the navel orangeworm. The clerid is a predator and is rather widely spread in central California. The larvae of the clerid were in fair abundance in the experimental orchard at Linden in the late spring and early summer of 1960. They were sufficiently numerous to indicate that they are probably of some importance in destroying navel orangeworm caterpillars. In 1960 specimens of the predator were taken in nut samples collected as early as October 21.

The common insect fungus—*Beauveria bassiana*—also has been found attacking larvae of the navel orangeworm.

Sanitation

The most important breeding sources for the navel orangeworm are the sound nuts left on the ground and in the trees. The pest could be very well controlled if the crop refuse in the orchard, around hullers and packing sheds, were completely destroyed before the new crop is subjected to attack.

By early summer, winter rains, cultivation, and irrigation take a heavy toll of the nuts on the ground. During the fall, winter, and spring the nuts left in the trees continue to drop, but usually enough remain to carry the insect over to the next season.

In the experimental orchard at Linden, samples of nuts were collected from the ground and from the trees from November 1959 into June 1960. After June 13, cultivation and irrigation completely eliminated nuts on the ground. The last collection from the trees was made on June 21 when a great deal of searching was required to find any nuts. Navel orangeworms were found in all collections, but the nuts remaining in the trees exceeded those on the ground in carrying over the pest to the new crop.

In general, the navel orangeworm has presented a more serious problem in the smaller orchards which are more influenced by adjacent planting than are the larger orchards. Also, the navel orangeworm is frequently most troublesome about the homestead where more hosts—mummified fruits and nuts—are usually present and effective sanitation programs are difficult to operate.

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The insect fungus—Beauveria bassiana—was identified by Edward A. Steinhaus, Professor of Insect Pathology, University of California, Berkeley.

Seasonal Trend of Infestation of the Navel Orangeworm in Unharvested Walnuts on the Ground and in the Trees, and the Number of Clerid Larvae per 100 Nuts.

Date (1959–60)	Walnuts from ground				Walnuts from trees			
	Number	Infested nuts with living larvae and pupae		Clerid larvae*	Number	Infested nuts with living larvae and pupae		Clerid larvae*
		Per cent	Average number per infested nut			Per cent	Average number per infested nut	
Nov. 25	200	18.0	1.8	0.0	200	20.0	3.4	0.0
Dec. 18	200	16.5	2.0	0.0	200	25.0	3.0	0.0
Feb. 16	200	35.0	2.8	1.5	52	32.7	3.0	0.0
March 16	200	33.5	3.0	0.5	100	39.0	4.3	1.0
March 29	...	...	..	..	100	54.0	6.1	11.0
April 5	200	10.0	1.5	0.0	100	36.0	4.2	0.0
June 2	335	1.7	1.7	14.5	...	...	..	..
June 13	122	4.9	1.8	8.2	...	...	..	..
June 21	...	..	..	..	100	24.0	7.4	17.0

*Cymatodera ovipennis LeC.