Two imported parasites of the navel orangeworm (one of the important pests of almonds and walnuts in California) have demonstrated biological control possibilities and are being given further biological and mass culturing studies at Berkeley.

L. E. CALTAGIRONE · K. P. SHEA
G. L. FINNEY

Parasites to aid control of NAVEL ORANGEWORM

THE SIX SPECIES of natural enemies of the navel orangeworm, *Paramyelois transitella* (Walker), in California have not been effective in keeping the pest at a level below that of economic importance. A project to introduce and colonize other biotic agents against the navel orangeworm was initiated in May, 1961.

The chances of introducing and establishing any species of natural enemy to reduce the population of its host depend, among other things, on the availability of susceptible stages of the host. Generally, the more stages of the host that are exposed, the greater the possibilities of having a complex of species of natural enemies that may aid in keeping a pest at a lower density. In the case of the navel orangeworm, only the egg and adult stages are exposed. The first instar larva is unprotected for a short time while wandering to get into a nut. Once the kernel is reached, the immature stages (larvae and pupae) are protected not only by the hulls and shell that enclose the kernel, but also by the web spun during the active feeding period. This condition called for consideration of two kinds of parasites: those that oviposit and complete their development in the egg of the host (egg parasites), and those that oviposit in the egg and complete their development in the larva of the host (egg-larval parasites).

Phanerotoma flavitestacea ovipositing in egg of the navel orangeworm.

With the assistance of Shmuel Gothilf of the National and University Institute of Agriculture at Rehovoth, Israel, several hundred adults of the braconid, *Phanerotoma flavitestacea* Fischer, were imported into the quarantine introduction laboratory, Berkeley, in September 1962. Although in Israel this parasite attacks the carob pod moth, *Ectomyelois certoniae* (Zeller), it readily oviposits and develops in the navel orangeworm.

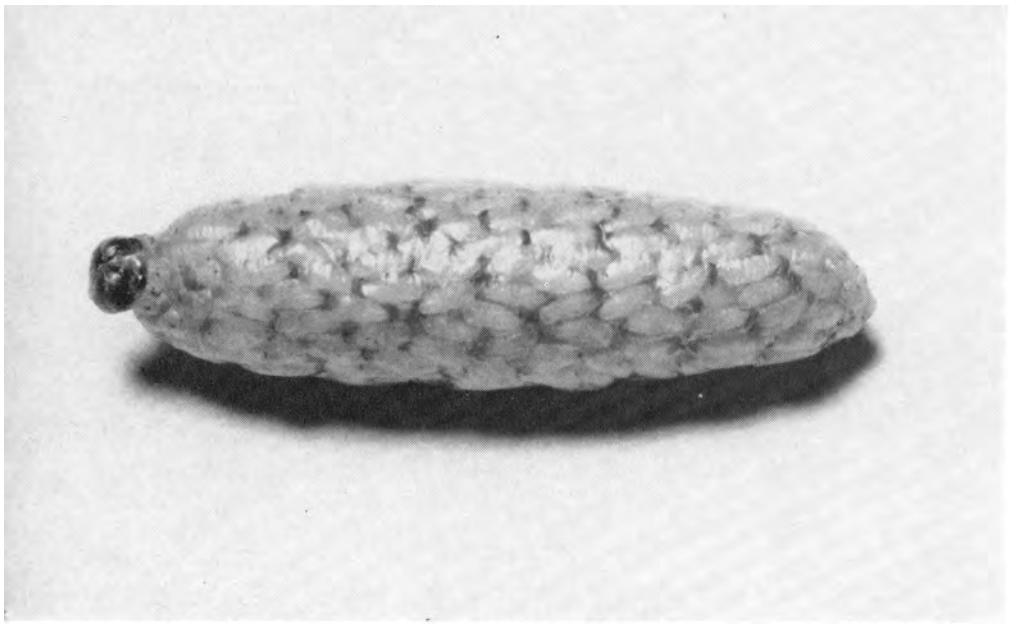
The adult *P. flavitestacea* is a wasp about 0.18 inch long, orange-yellow in color with brownish markings on the wings and thorax. This species is an egg-larval parasite; the female oviposits in the egg of the navel orangeworm, and the larva completes its development after the host has spun its cocoon. The fully developed larva spins a cocoon inside that of the host, the adult emerging from it after the pupal stage has been completed.

Laboratory studies have shown that the reproductive potential of this species is high; one female lays over 350 eggs. It has also been noticed that the females are highly discriminative; that is, they will restrain from ovipositing in hosts that have already been parasitized. When a female is given a limited number of navel orangeworm eggs in a confined environment, she will parasitize all of them in a rather short time, then she will frantically look for unparasitized hosts; only after a prolonged search does this restraint break down, and allow the female to lay eggs in already parasitized host eggs.

Native to Mexico

The navel orangeworm is considered native to Mexico, so an exploration trip was made by the senior author to look for natural enemies. As a result, another egg-larval parasite, an encyrtid in the genus *Holcothorax*, was found. Several shipments of parasitized navel orangeworm larvae yielded about 20,000 adult *Holcothorax* which were used as the parent stock for the mass culturing of this species in the insectary.

Holcothorax sp. is a remarkable parasite which exhibits the unusual habit of polyembryony: a single egg produces many embryos which give rise to as many



Larva of the navel orangeworm parasitized by Holcothorax sp. Each cell contains one pupa of the parasite.

adults after the developmental period is completed. The female lays approximately 60 eggs, but this does not adequately describe the reproductive capacity of the species. Only one egg is normally laid in each host egg; there it divides into many cells, each one producing a larva. These larvae feed in the host larva which, although parasitized, is able to complete its development and spin its cocoon. Soon after, the parasites take over and kill the host. After reaching maturity each parasite larva forms a cell in the dried remains of the host where it pupates. About 500 adult parasites will emerge from an average navel orangeworm larva, and as many as 1,200 have been reared from a large host larva.

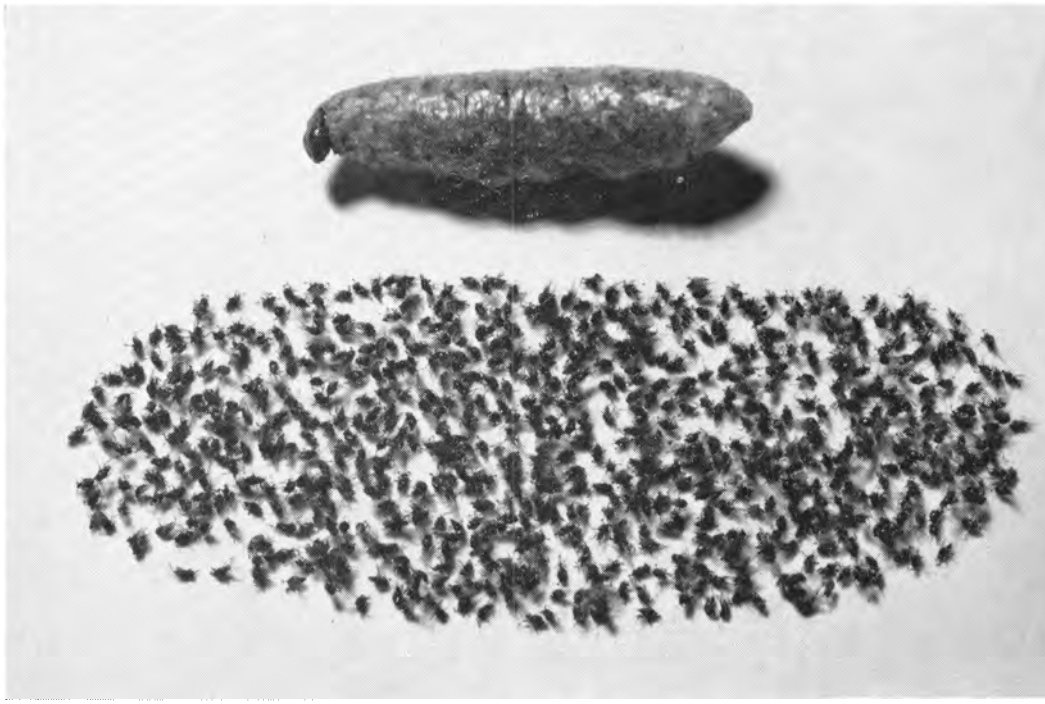
An intensive sampling program has been carried out in northern California almond orchards to determine the densities of the navel orangeworm throughout the growing season as well as during the winter months. *P. transitella* is an unevenly brooded insect, with all stages available as potential hosts during the growing season. It has also been found that although the pest is unevenly brooded, two distinct peaks of oviposition occur in the field. The first occurs in the spring, just before the green nuts crack and become susceptible to attack. This peak is the result of the activity of emerging adults which have matured in old nuts left in the trees from the previous year's harvest. Since the old nuts contain larvae of various stages through the winter, the spring emergence and oviposition peak last for a period of about two to three weeks. The moth seems to have the ability to spread rapidly during this period and cause considerable damage to the early maturing varieties.

The second peak occurs in late September and early October after most of the nuts have been harvested. This brood is the result of emerging adults which have matured on the new crop. Since the availability of susceptible nuts has been greatly reduced by harvesting, the moth concentrates its oviposition on the nuts left in the trees after harvest. During the winter months, up to 90% of the unharvested nuts may be infested with various stages of the navel orangeworm.

Since the introduced parasites are restricted to parasitizing the egg stage, spring and fall would seem to be the ideal times to attempt the establishment of the species. Weekly samples are being continued to keep a close surveillance on the field population so that a mass culturing program can be planned to coincide with peaks in field oviposition activity.

Techniques are being developed for the mass culturing of *P. flavitestacea* which will develop on the eggs and larvae of both the navel orangeworm and the Mediterranean flour moth; and *Holco-*

From this parasitized navel orangeworm larva, 789 adult Holcothorax sp. emerged.



thorax sp. which will develop only on the navel orangeworm.

The culturing of the navel orangeworm was initiated in this laboratory in February 1962, using off-grade and fragmented walnut meats as food for the larvae. The following May a medium of Pablum, honey, glycerine, and water—commonly used for wax moth production—was substituted for walnut meats. The medium currently in use is a modification of the Pablum medium in which wheat bran has been substituted for Pablum. The moth oviposition units and oviposition substrate have been developed and quite well standardized at this time. The egg production available using present methods and equipment is considered adequate to support the parasite production demands of the foreseeable future.

Although methods are being developed for culturing *P. flavitestacea* on either host, the Mediterranean flour moth will probably be the one utilized for large scale production because the eggs of this host can be obtained in larger numbers more efficiently in terms of labor and space than those of the navel orangeworm. When the release program develops and expands, the production of this parasite can be conservatively predicted at 100 to 150 thousand per month.

The culturing method for *Holcothorax* is rapidly shaping up. The unique biology of this parasite should lend itself to the production of large numbers of adults in a mass culture program.

Leopoldo E. Caltagirone is Assistant Entomologist, Kevin P. Shea is Laboratory Technician II, and Glenn L. Finney is Associate Specialist in the Division of Biological Control, University of California, Berkeley. Photos were taken by F. E. Skinner.

CALIFORNIA AGRICULTURE

Progress Reports of Agricultural Research, published monthly by the University of California Division of Agricultural Sciences.

William W. Paul.....*Manager*
Agricultural Publications

Jerry Lester.....*Editor*
California Agriculture

141

MIRIAM REVZAN

MILK CONSUMPTION *and* TODAY'S CONSUMER