Project No.: 96-KD1, Release of *Goniozus legneri* for NOW Control
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Objectives:
I. Establishment of Guidelines

Almond growers lose millions of dollars to insect pests each season; the navel orangeworm (NOW) is arguably one of the most important insect pests. To control NOW, both large and small farming operations have been using augmentative release of the larval-parasite *Goniozus legneri*. However, the effectiveness of *Goniozus*-release programs has not been scientifically documented. Here, we report on the second year of a 3-4 year study that will document the effectiveness of current *Goniozus* release programs and suggest improvements to release methodologies.

I. Release methodology.

A series of field tests were made to determine the success of pupal release in gelatin capsules. *Goniozus* pupae in gelatin capsules were placed in the crotch of almond trees in the morning and the foraging activity of predators were observed. In the afternoon, the capsules were collected and the *Goniozus* pupae were examined. The experiments were conducted during Summer and Fall in an almond orchard that did not use insecticides for ant control.

Results show that the release of both "white-capped" pupae (e.g., newly developed) and "black-capped" pupae (e.g., well developed pupae that will soon hatch to adults) were subject to significant mortality from predation. In all trials, ants quickly found the capsules during the first few hours after field-placement. The most common ant species were the native gray ant, *Formica aerata*, and the southern fire ant, *Solenopsis xyloni*. The ants entered the capsules and chewed through the *Goniozus* cocoon to kill and feed on the pupa inside. Results in 1995 showed that 96% of the black-capped pupae survived (at the time of release, ~20% of the adults had already emerged and were in the gelatin capsules); in contrast, only 22% of the white-capped pupae survived. In 1996, we observed a greater mortality of the black-capped stages, including mortality of adult *Goniozus*, from ants, as they emerged from the cocoon. Physical factors also had a greater effect on the survival of white-capped pupae as the many of the gelatin capsules were blown from the trees to the orchard floor, before adult *Goniozus* emerged, and the moisture from cover crops and irrigation destroyed the gelatin capsules to dissolve, killing the pupae inside.

From work in 1995 and 1996, we suggest that insectary material be stored until adult *Goniozus* begin to emerge. The opened capsules can be placed in a dixie cup that has been streaked with honey. The honey will provide food for the adult

Goniozus and increase their field longevity. To complete this release program, we have to determine the movement of adult *Goniozus* in the field to determine how many release sites per acre will provide adequate distribution of insectary material.

II. Release effectiveness.

To scientifically evaluate *Goniozus* releases, we developed a methodology to determine field parasitism rates. First, NOW are produced in a laboratory colony. Then, when the NOW larvae reach the second instar they are used to inoculate unshelled almond nuts. The inoculated nuts are stored singly in the cells of plastic rearing containers and held at 82°F. After ~7 days, larval development is observed and those nuts that have been successfully infested with an NOW larvae are removed and stored at 55°F to slow NOW development. For field experiments, the "sentinel nut" is placed into a wire cage (~2 sq inches) that can be stapled to the almond tree.

Experiments used either a replicated split-plot design with *Goniozus*-release or no-release plots in a single orchard, or paired orchard blocks. In all tests, 100 sentinel nuts were spaced evenly throughout each plot. *Goniozus* were then released at rates between 350-700 *Goniozus* per acre (typical release rates are between 250-350 *Goniozus* per acre per release). After 14-21 days, sentinel nuts were removed and the number of NOW parasitized was recorded. The commercial orchards used were between 40-90 acres in size, allowing for large plot size to reduce movement of *Goniozus* between plots or orchards. These field tests were conducted in Butte, Merced, Madera, Kings, and Kern Counties.

Data from these trials are currently being analyzed. However, a preliminary analysis indicates that in orchards with low NOW pressure (e.g., nut infestation rates of <5%), NOW parasitism rates were between 0-25%. Therefore, *Goniozus* release can reduce the NOW population by up to 25% on any NOW generation (this may amount to a greater reduction when viewed over the entire season because of multiple NOW generations). In orchards with high NOW pressure (e.g., nut infestation rates of >10%), NOW parasitism rates were generally higher, between 10-40%. However, the increase in percent parasitism was not enough to lower high NOW populations to acceptable levels. In our trials, the data indicate that changes in release methods or release rates are needed before would *Goniozus* releases can be used to lower high density NOW populations in a single season.

III. Overwintering Sanitation.

One of the more controversial practices that has been suggested is the incomplete removal of overwintered mummies to supply overwintering host sites for *Goniozus*. The following experiment is based on these facts: overwintering almonds serve as a host for NOW, orchard sanitation reduces NOW infestation rates, and there is a positive correlation between the numbers of overwintering nuts and *Goniozus*. Therefore, incomplete orchard sanitation will lead to higher numbers of NOW and *Goniozus*; however, the resulting levels of NOW percent parasitism or NOW nut infestation at harvest are not known.

To investigate, we used 3 commercial orchards that have a NOW control program of winter sanitation and *Goniozus* release. In each, a single 8-acre section was not sanitized, and all overwintering nuts were left on all trees. The average number of mummies per tree was determined. Populations levels of NOW and *Goniozus* in the overwintered nuts were determined every 2 months. More importantly, the number of NOW and *Goniozus* moving out from the unsanitized portion of each orchard was sampled to determine whether overwintering mummy nuts (combined with *Goniozus* release) provide a source of more NOW or *Goniozus*. To sample, transects were laid through each orchard, NOW and *Goniozus* populations were monitored along these transects with NOW egg traps and with sentinel nuts. At harvest, nuts will be taken from the unsanitized sections and at rows 1-10, 11-20, 21-30, and 31-40 away from the unsanitized section.

Results showed that *Goniozus* did not overwinter as well as the NOW. Initial data analysis shows that only the adult *Goniozus* stage made it through the winter period. In contrast, NOW overwinters in the larval stage and there was very little mortality of NOW larvae in the nuts during this period. The biology of *Goniozus* may explain the high winter mortality. This parasite was imported from regions in Texas and Mexico where Winter temperatures are warmer than those in California's Central Valley. The *Goniozus* larval stages may simply not survive at colder temperatures. To test, we are using temperature cabinets to develop life table parameters for each *Goniozus* stage (e.g., at what temperature can it survive). Because of the poor Winter survival, we don't believe that post harvest *Goniozus* release (e.g. late September-October) are as effective as Spring or Summer releases. This information can also be used to develop a temperature based development model that will be combined with a model on NOW development to help determine proper release timing.

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