Project Number 81-F8

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BIOLOGICAL CONTROL OF NAVEL ORANGEWORM

Semi-Annual Report

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The goal of this project has been to acquire new natural enemies of navel orangeworm for California as a supplement to the already established parasite, Pentalitomastix plethoricus. Surveys throughout the native range of navel orangeworm in North, Central and South America as well as in other world regions inhabited by a related lepidopteron, the carob moth, have produced many different parasitic species, seven of which were mass reared and released in experimental almond orchards in California beginning in 1979.

Initial results showed that three larva-attacking species, Parasierola emigrata (Rohwer) (biparental Texas strain), Goniozus legneri Gordh, from Uruguay and Argentina, and Diadegma sp. from South Australia were able to reproduce and overwinter in release orchards. Therefore, in 1981, emphasis was placed on spreading these and a more recently acquired egg-attacking parasite, Chelonus mccombi Marsh from Texas, in commercial non-sprayed almond orchards in Central and Northern California. However, over 90% of the additional acreage was sprayed with 1-4 applications of insecticides during the late spring and summer period, which greatly reduced navel orangeworm infestations. This plus suspected direct effects of the insecticides on the parasites themselves, precluded known establishment in the extended acreage.

Two species, Parasierola emigrata and Goniozus legneri, were observed to persist in the original unsprayed orchards although considerable dispersal of these parasites out of the orchards occurred to the extent that their presence was measured at under 10% of the abundance they showed in the release year (1979). As surrounding orchards were under regular insecticidal spray schedules, it is assumed that dispersal back was greatly restricted.

Of particular importance has been the measurement of the true impact of both parasites, the widely-established Pentalitomastix and the new Goniozus on navel orangeworm in the orchards. To determine this it was essential to devise a method of sampling which would accurately measure the initial density of navel orangeworm at the time that parasitization was occurring. Mummy almonds which contain overlapping generations of orangeworms, were not suitable for the determination of initial density. However, orangeworms sampled within three weeks of hull split in August appeared to offer the best possibility for such density measurement.

Thus, almond samples taken within 3 weeks or earlier of hull-split were confined individually in metal-screened plastic vials and incubated at 80° F, 14-h light for at least 4 months to allow for complete emergence of moths and parasites. Although most moths and parasites emerged within 3 months of sampling, a smaller percentage (usually under 5%) showed extended emergence through mid-January, or more than 4 months after sampling. The initial densities per tree were calculated from the total emergence from 100 hull-split almonds that were sampled at random within the tree. Final densities after parasitism were also calculated.

An analysis was used to measure whether the parasite responded with a greater killing rate to higher orangeworm densities than to lower. The analysis compared the Log_{10} Initial Density + 1.0 against the difference between this and the Log_{10} Final Density + 1.0, or k-value. Significant correlation coefficients of 0.800 or greater were found in this relationship in areas where Goniozus legneri and Parasierola emigrata were established at 4 orchards located near Wasco, Chowchilla and Chico. This gave statistical evidence for the ability of Goniozus and Parasierola to control navel orangeworm. Of these two parasites, Goniozus showed the highest correlation coefficients and gave the highest field-reproduction rates.

Similar analyses performed on data gathered from areas where only Pentalitomastix was present did not show these high correlation coefficients, indicating that this parasite was not significantly responsive in a controling sense to navel orangeworm in August. Laboratory data show that Goniozus is capable of parasitization at temperatures in the high 80's through the mid 90's, while Pentalitomastix does better at cooler temperatures in the mid to low 80's. Temperatures above 85° F cause Pentalitomastix to produce mostly male offspring, while Goniozus produces a preponderance of female offspring from 70° F to the mid-90° F range. Therefore, it is suspected that Pentalitomastix is a cooler weather parasite which is capable of controling influences only during the cooler portions of the growing season, while Goniozus is well adapted to controling navel orangeworm over a broader temperature range including the hottest months.

As was pointed out earlier, the continuous overlap of navel orangeworm generations on mummy almonds has confounded our ability to estimate an initial density and precluded our ability to measure parasite impact on navel orangeworm inhabiting mummies. Two possible ways to get around this would be to take weekly samples of mummy almonds beginning after harvest, which is impractical, or to artificially inoculate and hang mummies in the trees, which is even more impractical and artificial. With vagile species of host moths and parasites the replicate number must necessarily be high, so labor costs would be the main restricting factor in these approaches. Thus, we may not be able to judge the role of Pentalitomastix and Goniozus during cool seasons. I have separated data of the emergence of early, mid and late emerging orangeworms and parasites from December mummy samples and will subject each category to a separate analysis, in an attempt to reduce the overlapping generation effects. Other field sampling techniques are being explored. A complete set of data and analyses will be submitted in a later report.

Given the omnipresence of Pentalitomastix in unsprayed orchards and its occurrence at reasonably high parasitization rates in all seasons sampled, the biological control influence of this parasite should not be minimized. Both parasites, Pentalitomastix and Goniozus, operating together in the orchard could produce orangeworm densities that are below the economic threshold. Some of our 1981 data from 15 year old unsprayed orchards where trees averaged a minimum of 10 mummy almonds per tree at harvest and where both parasite species were present, showed total reject rates of below 3%.

Proposal For Maximizing Biological Control

In areas where peach twig borer, San Jose scale and mites pose a special threat, it is recommended that dormant insecticide and oil treatments be applied thoroughly to keep these pests in check. We have not witnessed any adverse effects on the persistence of Goniozus or Pentalitomastix from these treatments. However, any insecticidal sprays applied during the active growing season from mid-April through late autumn are expected to interfere with parasitic control, thereby greatly reducing its impact on control of navel orangeworm and possibly resulting in the eradication of both parasites from the orchard. Reinvasion of parasites would then be dependent on the proximity of reservoir populations in neighboring orchards.

Annual inoculative releases of Goniozus legneri will result in local reproduction and some direct navel orangeworm control. The degree of control will depend on the numbers released and the thoroughness with which the parasites are manually spread in an orchard. Ideally, each tree containing mummies should be inoculated. A minimum of 1,000 Goniozus per acre is recommended, the parasites being placed directly in convenient crevices of the tree scaffold at arm's height. They will fly or crawl out to the mummy almonds located in the scaffold. Releases should begin when daytime orchard temperatures reach 75° F (late April, early May). At release rates of more than 1,000 parasites per acre, liberations may begin a few weeks earlier when temperatures are in the high 60's. July releases are also effective but there will be less time for field produced offspring to affect orangeworms before harvest. Releases may continue after harvest and through the warm months of late autumn, giving parasites several additional months for field multiplication and navel orangeworm destruction on mummies, and a greater impact potential during the next growing season.

Mummy almonds that are picked from the trees should not be removed from the orchard, but as was earlier recommended for Pentalitomastix establishment, they should be placed in window-screened water-protected containers and hung in orchard tree scaffolds spread throughout the orchard. Parasites can thus escape through the screen leaving any moths behind. Care should be taken to protect these containers from the direct blast of dormant sprays in winter.

At least two years of parasite releases are recommended for maximum effectiveness, although the effects of the first year's release should be noticeable at the first harvest. Success will depend in part on the amount of insecticidal drift from neighbors, which can be serious especially if the almond acreage is under 15 acres and if stone fruits, grapes, cotton, sweet corn, or other such crops surround the orchard. The need for continuous yearly parasite releases will depend in part on these factors.

Parasites are currently available at two commercial insectaries at a cost of $20.00 per 1,000 Goniozus legneri. The University has limited supplies needed for continued experimentation.

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DEPARTMENT OF ENTOMOLOGY

DIVISION OF BIOLOGICAL CONTROL
RIVERSIDE, CALIFORNIA 92521
(714) 787-4674

6 January 1982

Mr. Robert K. Curtis
Associate Research Director
Almond Board of California
P.O. Box 15920
Sacramento, CA 95852

Dear Bob:

Enclosed are two copies of our semi-annual report pertaining to biological control of navel orangeworm. Jim McMurtry will submit a separate report on his predatory mite introductions.

Sincerely,

E. F. LEGNER
Entomologist

CC: J. McMurtry
Admin.

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81-47

Project No. 80-F7: Biological Control-Almond pest mites.

Project Leader: Dr. J. A. McMurtry
University of California
Division of Biological Control
Riverside, CA 92521
(714) 787-5715

Objectives: To study the effects of released predators on the control of spider mites on almonds in the Central Valley of California.

Interpretive Summary:

Three predatory mite species were released in three orchards in Kern, San Joaquin and Butte counties. The species released this year were *Amblyseius stipulatus*, originally from the Mediterranean area and now established in southern California; *A. elinae* from Australia (also released on almonds last year); *A. californicus*, a native species found mainly in southern California; and *Phytoseiulus persimilis*, introduced from Italy. Spider mite populations did not become high in the plots and none of the introduced species was recovered in subsequent collections of leaf samples. These plots will be checked in early summer 1982, to determine if any of the introduced species became established.

Mite and predator populations were monitored in two adjacent orchards in Kern County, one having a clover cover crop and the other having the standard practice of a minimal weed cover. Supplementary releases of the predator *Typhlodromus occidentalis* were made on some trees in both orchards. Although spider mite populations were considerably lower in the orchard with clover cover crop, this was attributed in part to an acaracide spray which was inadvertently applied to that orchard. There was a trend toward higher *T. occidentalis* and lower spider mite populations on trees on which predators were released, but there was considerable variation among sample trees.

Experimental Procedure

1. Colonization of introduced predators.--The main release plot was in Kern County, where *Amblyseius stipulatus*, *A. elinae* and *A. californicus* were each released on 4 trees at the rate of 200 per tree at biweekly intervals beginning on May 26 and ending July 21 (total 4000 of each species). Leaf samples (24 leaves/tree) were taken from each release and 8 non release trees at biweekly intervals from May 26 to August 17. All active stages of spider mites and phytoseiid mites were counted in the laboratory and the phytoseiids were mounted on slides for subsequent species determination. In Butte County a single release was made of *A. elinae* (1000), *A. stipulatus* (1500) and *Phytoseiulus persimilis* (2000). A single release of 2000 of each of the same species was made in San Joaquin County.

2. Cover crop and *Typhlodromus occidentalis* release experiment.--Two adjacent orchards in Kern County were selected for this experiment, one orchard had a clover cover crop and the other a standard minimal weed cover. Twelve sample trees were selected in each orchard, 6 of which received releases of *Typhlodromus occidentalis* at rates of 200/tree on each of 4 dates (May 4, June 8, 22 and July 5). Twenty leaves were picked from each sample tree at weekly intervals from April 8 through July 20. All stages of spider mites and phytoseiid mites were counted in the laboratory.

Results

1. Colonization of introduced predators.--None of the phytoseiid species released was recovered in samples during 1981. Biweekly samples in the Kern County plot showed only low populations of both spider mites and phytoseiid mites (Table 1). All phytoseiids examined were *T. occidentalis*.

2. Cover crop and *T. occidentalis* release experiment.--Spider mite populations were markedly lower in the orchard with a clover cover crop (Table 2). However, it was learned in late July that an acaracide spray was inadvertently applied to the orchard with the clover ground cover. Therefore, the effect of the clover could not be adequately evaluated, because the differences can be attributed at least in part to the effect of the spray. There was a trend toward lower spider mite and higher phytoseiid mite populations on the *T. occidentalis* release trees, but there was considerable variation among sample trees.

Discussion

I feel that we have made a reasonable attempt to establish *Amblyseius stipulatus*, *A. elinae*, *A. californicus*, *A. victoriensis* and *Phytoseiulus* (the last 2 were released last season), and if we do not recover any of these species in surveys next season, we can probably conclude that they will not survive in commercial almond orchards in the Central Valley. It is my opinion that the establishment of additional mite predators on almonds to augment *T. occidentalis* would be of significant benefit, and that additional introduced species should be tried in the future.

Table 1. Spider mite and phytoseiid mite (*T. occidentalis*) populations in predator release plots. Kern County. 1981.

Species Released	Sample Dates 5/26	6/8	6/22	7/5	7/22	8/3	8/17
	Mean Number of *Tetranychus* per leaf[a]						
1. *A. californicus*	3.2[b]	2.3	0.0	0.0	0.3	0.16	0
2. *A. elinae*	1.6	5.0	0.0	0.04	0.5	0.46	0
3. *A. stipulatus*	1.2	2.3	0.04	0.0	0.6	0.29	0
4. -- check	1.3	2.5	0.04	0.0	0.4	0.4	0
5. -- check	2.3	4.8	0.04	0.0	0.5	0.12	0
	Mean Number of *Typhlodromus occidentalis* per leaf[a]						
1. *A. californicus*	0.01[b]	0.26	0.3	0.0	0.04	0.08	0.0
2. *A. elinae*	0.03	0.44	0.16	0.08	0.29	0.16	0.0
3. *A. stipulatus*	0.02	0.69	0.16	0.0	0.08	0.16	0.0
4. -- check	0.0	0.18	0.25	0.0	0.21	0.04	0.0
5. -- check	0.02	0.54	0.04	0.04	0.12	0.29	0.0

[a]Based upon 24 leaves per tree.

[b]Each treatment replicated 4 times.

Table 2. Spider mite and phytoseiid populations in an orchard with standard cultivation and one with a clover ground cover, on trees having releases of *T. occidentalis* and trees having no releases. Kern County, 1981.

	Spider Mites[a]				Phytoseiid mites[a]			
	No Clover		Clover		No Clover		Clover	
	Pred. Rel.[b]	Non Rel.	Pred. Rel.[b]	Non Rel.	Pred. Rel.[b]	Non Rel.	Pred. Rel.[b]	Non Rel.
6-1	0.11	0.24	0.01	0.03	0.03	0.03	0	0.01
6-8	0.41	0.38	0.03	0.08	0.01	0.03	0.03	0
6-15	1.15	0.69	0.08	0.03	0.07	0.06	0.02	0.02
6-22	1.13	0.78	0.37	0.01	0.09	0.20	0.01	0.01
6-29	1.11	2.06	0.30	0.39	0.25	0.09	0.08	0.09
7-5	0.28	0.25	0.07	0.43	0.33	0.15	0.07	0.08
7-13	2.33	1.01	0.16	0.23	0.01	0.02	0	0
7-20	5.88	6.30	0.08	0.13	0.16	0.13	0	0

[a]No. active stages/leaf, based on 20 leaves/tree.

[b]Trees which received releases of *T. occidentalis* at a rate of 800/tree.

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Bob — I took care of

January 8, 1982

Dr. Robert K. Curtis
Almond Board of California
P.O. Box 15920
Sacramento, CA 95852

Dear Bob:

Enclosed are two copies of my part of the biological control project on almonds.

Sincerely yours,

Jim

J. A. McMurtry
Professor

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