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ARTICLES

PARTICIPATORY RESEARCH IN PEST MANAGEMENT: THE IMPACT OF GENERALIST PREDATORS ON THE PEACH TWIG BORER IN PEACHES

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Introduction

The explicit inclusion of farmers in the agricultural research and extension process has emerged as a central theme in the task of developing more sustainable production systems. Though this call for farmer participation has become more widespread, few studies have documented the actual process of farmers participating with scientists in defining, implementing,

and/or evaluating research. In 1991, we began just such a collaborative grower-scientist peach insect pest management research project. The objectives were to develop a research agenda in cooperation with peach growers, implement scientific studies that addressed questions raised by farmers, evaluate the effectiveness of this participatory approach in generating relevant information, and document the overall process.

This paper reports on two of these objectives. First, we provide a brief description of the development of the research agenda. Second, we present the results from the on-farm studies.

Developing a Research Agenda

The research program was developed in collaboration with members of the non-profit organization California Clean Growers Association (CCGA) utilizing a

University of California and the United States Department of Agriculture cooperating

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methodology called participatory rural appraisal (PRA). PRA combines the techniques of secondary data review, semi-structured interviews, observation of farm activities, and formal and informal group meetings to identify and evaluate specific needs. From this work, we developed a research program for the 1990-91 season. Our focus was on the peach twig borer (PTB), *Anarsia lineatella*, which was identified by peach farmers as the key insect pest in their production systems. Farmers further expressed interest in understanding and improving biological and cultural controls of PTB that would work in conjunction with *Bacillus thuringiensis* (Bt) and pheromone confusion programs.

Following the 1991 field season, a focus group meeting was held with the 11 member CCGA Board of Directors, and four observers: three agricultural scientists with expertise in entomology, agronomy, and sustainable agriculture, and a meeting recorder who took notes as well as made an audio recording. The purpose of the meeting was to evaluate the project and then refine future research activities. The outcome of the meeting was a set of farmer-generated research questions, which included:

- (1) What beneficial insects are eating PTB?
- (2) How does weather affect PTB survival?
- (3) What is the feeding pattern of PTB?

In response to these questions raised in our participatory format, a series of predator exclusion experiments were conducted in 1992 and 1993. Because PTB eggs and first instar larvae are difficult to find in the field, we utilized laboratory reared PTB larvae that were artificially placed into peach orchards. The experiments were designed to identify PTB mortality caused by "generalist predators" (e.g. ladybird beetles, green lacewings, ants, minute pirate bugs) and climatic conditions (referred to as "abiotic mortality"). The exclusion experiments focused on the impact of generalist predators because recent work by Daane et al. (1993) has shown that percent parasitism by the parasitoid complex attacking PTB in Fresno and Tulare counties is low. We also found that data generated by experimentally placing first instar PTB larvae onto peach shoots could also be used to provide some answers on PTB larval feeding behavior.

Materials and Methods

An experimental plot of 60 three-year-old Diamond Princess peach trees was established in 1992 at a farm in Dinuba, California. A second field site consisting of 100 twelve-year-old organically managed Flamecrest peach trees arranged 5 rows by 20 trees was established in 1993 at a farm in Kingsburg, California. Insect pest management at these sites included a dormant season oil application for the San Jose Scale (SJS),

Quadraspidiotus perniciosus; pheromone confusion for the oriental fruit moth (OFM) *Grapholita molesta*; and, at the Kingsburg site only, three applications of Bt at bloom for PTB. The plots received no applications of insecticides, fungicides, or fertilizers when experiments were underway. The orchard floors at both plots were covered by a mixture of planted cover-crops and endemic plant species. Vegetation was mowed at 3-5 week intervals during the growing season.

In each plot, actively growing terminal shoots with 3-5 lateral shoots located in the top meter of trees were selected. Shoots were either: (1) enclosed in an organdy cage, (2) partially isolated by a barrier of Tanglefoot placed around the base of the terminal shoot, or (3) open (no cage or Tanglefoot barrier). These treatments are hereafter referred to as full, partial, and no exclusion, respectively. Each shoot, or experimental unit, was infested with a single PTB larva. The PTB used were from a laboratory colony. Predator exclusion experiments were conducted to coincide with the emergence of larvae from hibernaculae determined by bud break and egg hatch in the first and second generations estimated by adult flight patterns monitored using Pherocon 1C pheromone traps. Second instar larvae were used for the overwintering generation and first instar larvae were used for experiments coinciding with the first and second summer generations. Thus, the PTB used in each experiment were the same age as the resident PTB larvae.

The full exclusion treatment was designed to remove the effect of predation. The partial exclusion treatment was designed to remove the effect of predation by the ant *Formica aerata*. Leaves and lateral shoots were removed from the base of the terminal shoot to assure that they did not touch adjacent shoots and provide a bridge for *F. aerata* or other predators to move onto the treatment shoots. The no exclusion treatment was designed to estimate the combined effects of predation and abiotic mortality. Natural enemies were manually removed from the full and partial exclusion shoots prior to placement of the larvae. All treatments were set in a randomized complete block (RCB).

Natural enemy species composition and relative abundance were measured by direct observation of individual no exclusion and partial exclusion shoots over a 30-second period. Shoots were monitored between 9:00 AM and 2:00 PM for a total of 4-7 days per experiment. Generalist predators observed on shoots were tested in laboratory no-choice trials to determine if they fed on PTB larvae.

Shoot attack rates measured by the presence of one or more damaged shoots per larva were determined by monitoring shoots for damage at 2-3 day intervals. On

the last sampling date, shoots in all treatments were removed from trees and dissected in the field using a dissecting microscope. This confirmed previously recorded shoot damage, corrected for damage in earlier sampling, and allowed for the collection of surviving larvae. The stage of recovered larvae was noted.

The overwintering generation experiment ran in 1992 and 1993, the first and second generation experiments were conducted in 1993. All experiments were terminated when larvae in the partial exclusion treatment were fourth and fifth instars, based on the Brunner & Rice (1984) phenology model. Ambient air temperature inside a weather shelter located in the center of each plot was recorded by a hygrothermograph at the Dinuba site in 1992 and by dataloggers at both sites in 1993. The dataloggers compared ambient air temperatures both inside and outside of the treatment cages.

Analysis of variance (ANOVA) was used to test for effect of treatment and block on: (1) natural enemy relative abundance, (2) larval attack rate, and (3) larval survival. Treatment means for larval attack rate and survival were compared with Tukey's multiple comparison test ($P < 0.05$).

Results

Generalist Predator Abundance

Generalist predators observed in this study included: the predatory ant, *F. aerata*, convergent lady beetle, green lacewing species, a minute pirate bug species, and two salticid spiders, *Sassacus vitus* and *Thiodina* sp. All of the predaceous stages of the observed generalist predators fed on PTB larvae in laboratory no-choice trials. The species composition and relative abundance varied between successive PTB generations and farm sites. *F. aerata* was the only predator observed on treatment shoots in all experiments, and only its densities were significantly higher in the no exclusion versus partial exclusion treatments. Relative abundance of all other generalist predators were not significantly different between these two treatments. This indicates that the Tanglefoot barrier significantly reduced predation pressure from *F. aerata*.

Shoot Attack Rate

The "shoot attack rates" indicate whether or not our methodology was valid; in other words, could we place insectary-reared PTB onto treatment shoots and follow their mortality, and did the treatments add a significant bias to the experiment? Overall, 58-89% of the PTB larvae placed on the shoots successfully began feeding. There was some influence of the imposed treatments, with the shoot attack rates significantly lower in the no exclusion versus full exclusion treatments in the 1993

experiments for the overwintering generation (72.5% vs. 88.7%) and first generation (63.7% vs. 78.7%). No significant differences were found in any of the experimental trials between the full exclusion and partial exclusion treatments. The latter results suggest that the foraging activity of *F. aerata* in the no exclusion treatment accounted for the reduced shoot attack rates. No significant differences in shoot attack rates were found among treatments in the overwintering generation 1992 and second generation 1993. From these results, we believe that the methodology used provided an effective way to manipulate PTB numbers in the field and follow larval PTB feeding patterns and abiotic and biotic mortality.

Survival of PTB Larvae

Larval survival rates were significantly lower in the no exclusion treatment as compared to the partial and full exclusion treatments in experiments conducted in the overwintering generation 1992, overwintering generation 1993, and first generation 1993 (Fig. 1a,b,c). *F. aerata* activity was significantly higher on no exclusion treatment shoots accounting for the only significant difference in generalist predator abundance. These results provide direct evidence that PTB larval survival significantly increases when *F. aerata* are excluded from foraging on shoots. The data also suggest that predation by *F. aerata* is the underlying cause that accounts for the differences in larval survival among treatments.

Larval survival during the second to fifth instars in the second generation 1993 also was significantly lower for both the partial and no exclusion treatments compared to the full exclusion treatment (Fig. 1d). We believe that PTB mortality in the partial exclusion treatment can be explained, in part, by the abundance of jumping spiders at this site, which was not significantly different between the partial and no exclusion treatments. Thus, the Tanglefoot barrier did not significantly restrict their movement, as compared to the movement of *F. aerata*, and this predator could account for the increased PTB mortality as compared to the overwintering and second generation experiments. In those earlier experiments, larval survival was significantly higher in the partial exclusion compared to the no exclusion treatments and no jumping spiders were observed on partial exclusion shoots. If jumping spiders were feeding on PTB larvae, this could account for the reduction of larval survival in the partial exclusion treatment relative to previous experiments. However, because no treatment differences were found between the partial and no exclusion treatments for the second generation 1993 (Fig. 1d), the effects of *F. aerata* and jumping spiders on larval survivorship cannot be distinguished.

(Figure not available)

Figure 1. Mean stage specific survival for (A) overwintering 1992, (B) overwintering 1993, (C) first 1993, and (D) second 1993 generations of PTB larvae. Data are means and 1 SE. Different letters above error bars in each graph indicate significant differences ($P < .05$, Tukey's multiple comparison test).

Discussion

The predator exclusion experiments provide evidence that predation by *F. aerata* significantly decreases PTB larval survival rates. The Tanglefoot barrier provided an effective means for segregating *F. aerata* from convergent lady beetles, green lacewings, and minute pirate bugs and the results indicate that these other generalist predators did not account for significant mortality of PTB larvae. In addition, larval survival rates were not significantly different between full and partial exclusion treatments. These results indicate that mortality due to generalist predators other than the ant, *F. aerata*, was minimal. The data from these experiments was put into "life table analysis" and gave similar results, showing that predation by *F. aerata* is the most important overall mortality factor for PTB larvae (Dlott 1993).

Now that we have identified the ant species, *F. aerata*, as the most important PTB predator, the question remains whether or not this predator can be manipulated to the growers' advantage. To answer this question we must consider the biology and ecology of *F. aerata*. Some ant species have the ability to aggregate to abundant food sources, such as extrafloral nectar, and once on the plants, also seek prey, thereby reducing herbivore populations. Such behavior has been used to argue that ants can be effective biological control agents. *F. aerata* appears to exhibit such foraging behaviors on peaches in the Central Valley. However, *F. aerata* also exhibits other behaviors, such as tending honey dew-producing scale and aphid insects. Shorey et al. (1993) report *F. aerata* tending several aphid species in plum trees in Tulare county. Aphid outbreaks in peaches are less common and have only occasionally been observed in peach orchards (J. Dlott & K. Daane, personal observations). It is unclear why plums are more susceptible than peaches to aphid attack, but one hypothesis is that extrafloral nectar production in some plum varieties is low. In the absence of abundant extrafloral nectar, *F. aerata* behavior may switch from foraging on extrafloral nectar to "tending" honey-dew producing aphid outbreaks, thus resulting in the classic disruption of biological control that is so well-known.

We are currently working with growers to determine which cultural practices can be used to "conserve" ant colonies. We have observed that in peach orchards managed without in-season, broad spectrum insecticides,

two ant species are commonly found, *F. aerata* and the southern fire ant, *Solenopsis xyloni*, with *F. aerata* being the dominant species. Further, it appears that cover crops on the orchard floor may affect ant species composition and numbers by providing alternative food sources (e.g. herbivore prey, seeds or nectar) as well as changing the microclimate and soil texture. Finally, substituting selective management tactics, such as Bt applications at bloom (Barnett et al. 1993) for broad spectrum insecticides which directly kill ants, is an important component in fostering biological control of PTB. We believe that a better understanding of how cultural practices increase or decrease population levels of ant species could lead to exciting new options in stone fruit integrated pest management.

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RELEASING PREDATORY MITES TO CONTROL CITRUS RED MITE AND TWO SPOTTED SPIDER MITES IN CITRUS GREENHOUSES

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Citrus nurserymen must keep citrus seedlings and nursery stock free of insect and mite pests for periods of more than 18 months before the trees are planted in the field. During this time the leaf tissue of these rapidly growing trees is a favorable habitat for mite pests such as citrus red mite (*Panonychus citri*) and two-spotted spider mites (*Tetranychus urticae*). Numerous insect species also can infest nursery trees, including citrus thrips, whitefly and brown soft scale. Traditionally, citrus nurserymen have depended upon pesticides to control nursery pests of citrus. However, pest mites and citrus thrips are developing resistance to many of the available pesticides. The primary objective of our research is to find natural enemies that can be released in greenhouse, lath house and open nursery situations that will control pests such as mites and thrips and so reduce the number of pesticides needed to control them.

In the first year of research, we utilized potted citrus seedlings (Old line Navel on Troyer rootstock) in three sets of experiments to evaluate predatory mite control of citrus red mite (CRM) and two-spotted spider mite (TSM) in a greenhouse situation. In each of the experiments, we pruned potted citrus seedlings to 10 leaves and infested them with 5 to 10 pest mites (CRM alone, TSM alone or 50% of each species). Two to three weeks after infesting the trees with pest mites we released 10 predatory mites/tree. There were four species of predatory mites in each experiment as well as nonrelease control trees and 12 trees were used for each of these release treatments. We sampled all 10 leaves per tree on a weekly basis for all stages of CRM and motile stages of the predacious mites. Experiments were conducted in a greenhouse during July 1993 through March 1994 and temperatures ranged from 70 to 105°F.

Control of CRM alone: To test the effects of predatory mites on CRM control we used 5 treatments; no predacious mite releases, *Euseius stipulatus*,

Galendromus helveolus, *Neoseiulus californicus* or *Euseius limonicus*. The *Euseius* species feed on pollen and leaf sap as well as CRM and so were able to maintain themselves even when prey was scarce. The choice of predatory mites was based on research experience that demonstrated that they are effective predators of CRM in orchards. At the time of predatory mite release, CRM densities averaged 22 mites/leaf. Releases of *Euseius limonicus* had no effect on the CRM densities and the predator's numbers decreased rapidly after release suggesting that this predatory mite is not suited for greenhouse citrus. The remaining three predatory mite species were effective in reducing CRM to densities of less than 5 mites/leaf three weeks after release. *Euseius stipulatus* maintained the highest predatory mite densities and reduced CRM to levels below 5 mites/leaf most quickly. Thus, in situations where CRM is the only pest, *Euseius stipulatus* would be the best control agent.

Control of TSM alone: To test the effects of predatory mites on TSM control we used 5 treatments; no predacious mite releases, *Euseius stipulatus*, *Galendromus occidentalis*, *Neoseiulus californicus*, or *Phytoseiulus longipes*. At the time of release, TSM densities averaged 9 mites/leaf. Each of these predatory mite species is known to be a voracious predator of TSM and all four species reduced TSM to less than 1 mite/leaf within 1 week of release. This is in contrast to the first experiment in which predacious mites required 3 weeks to reduce CRM to low levels. *Phytoseiulus longipes*, the predator that specializes in feeding on *Tetranychus* spider mites, dropped to very low numbers 1 week after release when its food became scarce. *G. occidentalis* and *N. californicus* dropped to very low numbers (<0.1/leaf) after 2 weeks. *E. stipulatus* (a pollen and leaf feeder) remained at elevated numbers (0.2-0.4 mites/leaf) for at least 3 weeks in the greenhouse. Thus, any of the four predacious mites tested were effective in reducing TSM and those that were tested with both pest species were more effective in controlling TSM than CRM.

Mixed populations of TSM and CRM: To test the effects of predatory mites on mixed populations of TSM and CRM we used 5 treatments; The treatments were: no predacious mites releases, *Euseius stipulatus*, *Galendromus occidentalis*, *Neoseiulus californicus* or *Euseius tularensis*. *Euseius tularensis* is common in San Joaquin Valley citrus and so we wanted to compare its effectiveness with the other three species. At the time of release, TSM+CRM densities averaged 29/leaf. *E. tularensis* was the least effective predatory mite, requiring 3 weeks to reduce TSM below 1 mite/leaf and showed no control of the CRM during the five weeks after release that they were monitored. *G. occidentalis* was the most effective predator in this situation of high mite densities and mixed pest infestation, reducing TSM

below 1 mite/leaf within two weeks and reducing CRM below 2 mites/leaf within three weeks. *N. californicus* and *E. stipulatus* were nearly as effective in controlling TSM, but control of CRM was only moderate. It was interesting to see that *E. stipulatus* and *N. californicus* were not as effective in controlling CRM when TSM was also present. This suggests that they prefer to feed on TSM.

The *Phytoseiulus* species of predatory mites are the most specialized feeders with a clear preference for *Tetranychus* prey. In our experiments they disappeared rapidly when their prey were consumed. The *Galendromus* and *Neoseiulus* species feed more generally on many spider mite genera and also do some pollen feeding. In our experiments, their populations declined when their prey declined, but not as quickly as the *Phytoseiulus* species. The *Euseius* species are the most general feeders, consuming pollen, mites and leaf sap. The *Euseius* species were able to maintain high predatory mite densities in all of the experiments even when their mite prey were scarce. Thus, *Euseius* species may be useful in situations where longer, but perhaps less effective, control of pest mites is needed.

The results of these experiments suggest that, in greenhouse citrus seedling situations, CRM will be more difficult to control than TSM. Any of the tested predatory mites (*E. stipulatus*, *P. longipes*, *G. occidentalis*, *N. californicus*, and *E. tularensis*) should be effective in controlling TSM when it is the only pest. *E. stipulatus* was the most effective predatory mite for long-term control when CRM was alone and *G. occidentalis* was most effective for a mixed pest population of CRM and TSM. The experiments were conducted in a greenhouse situation where temperatures and relative humidity were high. We plan to evaluate the results of this research in commercial greenhouse nursery situations during 1994-95.

IPM NOTES

PESTICIDE USE REDUCTION ASSESSMENT -- A CONGRESSIONAL REPORT

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Editor's note. The following report was compiled by the Senate Committee on Agriculture, Nutrition, and Forestry and was released on June 29, 1994. Its author is Michael D. Fernandez, Ph.D., Professional Staff Member. It is provided for your information as an indication of the level of interest Congress has in pesticide and IPM issues. For the sake of brevity, only the summary is presented here. However, the complete text makes interesting reading since it offers the best examples of IPM and pesticide reduction from 30 states. It provides a comparison of state programs, approaches, and agricultural scale. It

gives a sense of appreciation for the accomplishments we have made in California. I think you will find it interesting to compare the success stories of those states most actively involved in IPM. For complete copies, contact Pete Goodell.

Summary. The results of this survey indicate that more than 40,000 farmers in 32 states have made significant reductions in their use of synthetic chemical pesticides. A wide range of crops, including row crops, fruits and vegetables, are represented. This survey also indicates that a wide variety of alternative management practices -- from simple changes in application methods such as reduced application rates and band spraying, to more management intensive practices such as the use of biological control agents and economic threshold based decision making -- are being used.

It is important to note that many of these management practices were not adopted solely to reduce pesticide use.

It is clear from the data presented here that alternative pest management strategies have had a profound impact on farm profitability, through reduction in pest control costs and improved yields. Both environmental and economic considerations have influenced the management practices of these farmers.

* * * *

Rich Melnicoe has developed an excellent publication for requesting Section 18 and 24c emergency exemptions. He outlines the process and rationale thoroughly and with exceptional clarity. This is a must have document if you have ever applied or may apply for emergency exemptions.

To obtain copies, request them from Rich Melnicoe Western Region Coordinator, Pest Impact Assessment Program (PIAP)- IR4 Program, Dept. Of environmental Toxicology, Davis, 95616-8588. A phone number to reach him is 916 752-7634.