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Pesticide Experiments for a California Avocado IPM Program

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The three major insect pests of avocados in California are the omnivorous looper, *Sabuhdes aegrotata* (Guenee), the western avocado leafroller, *Amorbia cuneana* (Walsingham), and the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouche). In addition, there is one important mite pest, the avocado brown mite, *Oligonychus punicas* (Hirst). These pests and a list of currently registered pesticides for their control have recently been reviewed (1).

Avocado pests are generally kept under commercially acceptable control by a variety of beneficial insects, mites, diseases, and weather conditions so that the use of pesticides in California avocado groves is not a common practice as is the case in many other crops. However, with the dramatic increase in avocado acreage in Southern California over the past several years this situation may be changing. Increases in avocado insect pest problems have recently been reported (2).

To prepare for these potential pest problems a research effort was initiated to develop an Integrated Pest Management (IPM) program for California avocados. One aspect of this research is the evaluation of pesticides for control of avocado pests. As in any IPM program, pesticides should be applied only when all other means have failed and without which an economic loss will occur. Since there is a complex of beneficial insects and mites in all groves, pesticides which are selective for the pest and have a minimal adverse effect on these beneficials are preferred. The emphasis of this research is on selectivity and it can be achieved in several ways.

Pesticides may be selective by their chemical nature. Those that are stomach poisons only control chewing insects, such as worms. Other non-plant feeding insects such as parasites are not affected. Two such pesticides which are stomach poisons and are being evaluated for control of avocado worm pests are Kryocide®and *Bacillus thuringiensis* (Thuricide®). Pesticides which break down (degrade) rapidly may be selective. They control the pest but, since they are toxic only a short time, do not affect beneficials subsequently entering the treated area.

Another way of achieving selectivity is by applying the lowest effective rate possible. By applying only the amount required to control the pest the adverse effects on the beneficials can be minimized.

Selectivity can also be achieved by proper timing of the application. Applications made when the pest is most susceptible will increase the effectiveness of the material, require a lower dosage and may reduce the need for multiple applications.

The pesticides reported on here were evaluated for their ability to control pests and where possible for their effects on beneficial insects and mites.

EXPERIMENTS

In all ground experiments discussed below, an FMC hydraulic orchard spray rig was used. Pesticide sprays were applied at 400 psi to runoff. Total volume applied ranged from 3-9 gallons per tree, depending on tree size. All treated trees were separated by buffer trees to minimize drift problems. Ortho X-77®spreader at 4-8 oz/100 gallons water was added to all Kryocide® and Thuricide® treatments. A buffering agent, Sorba Spray 0-8-0® at 8 oz/100 gallons water, was added to phosphate or carbamate type treatments. The randomized block experimental design was used, with 5 to 6 single or double tree replicates per treatment. Where appropriate, data were analyzed using two-way analysis of variance and Duncan's New Multiple Range (DMR) Test at the 5% level. If required, data were transformed to $\sqrt{x}$. Both of the worm pests involved in these studies spend much of their time in "larval nests." We defined a nest as leaves webbed or tied together by one or more worms. Treatments were evaluated by examining nests for the presence or absence of worms, and when present, whether dead, alive, or parasitized.

The pesticides used in these experiments, with the exceptions of Dylox® 80 SP, Kryocide® 8F and 96W, and Orthene® 75 SP, are registered for use on bearing avocados in California. The 8F formulation of Kryocide® is no longer manufactured. There were formulation problems with it and this may explain why the 8F formulation of Kryocide® did not perform well in our experiments.

Avocado Brown Mite—Ground Application

During October of 1979 three acaricides were evaluated for control of the avocado brown mite (ABM) and possible effects on the predacious mite *Amblyseius hibisci* and the predacious beetle *Stethorus picipes.* Counts of both species of mites and the beetle were made on 15 leaves per tree for a total of 75 leaves per treatment. The test was conducted on Hass trees which were 9 years old.

Although conditions for this test were not ideal, results (Table 1) indicate that narrow range (NR 415) spray oil provided good control, whereas Thiolux®, a micronized sulfur, and wettable sulfur provided only poor to moderate control of the ABM. Since the temperature during this test was somewhat cool, the fuming action of the sulfur products may have been less than optimum, thus limiting their effectiveness.

As shown in Table 2, the predacious mites present were reduced significantly and were affected rather uniformly by all three acaricides. Counts of *Stethorus* beetles were very low on all trees. Most of those present were on the untreated trees, possibly indicating some adverse effect due to the treatments. It is not known whether the *Stethorus* were removed by the physical action of the spray application, killed by the chemical, or discouraged by removal of their prey (ABM).

TABLE 1. Effects of three Acaricides on Avocado Brown Mite, Robinson Grove, Couser Canyon, San Diego County. Applied October 11, 1979.

Treatment	Amount/ 100 gal. water	Average No. Avocado Brown Mites/ Leaf Days Post-Treatment			
		7	14	20	38
Untreated check	—	24.1a*	14.8a	7.4a	2.2a
Wettable sulfur 90W	8 lbs.	10.7ab	10.8a	4.8ab	2.2a
Thiolux® 80W	3.75 lbs.	6.6bc	6.9a	3.9ab	1.3ab
NR 415 oil (98% oil)	1.0 gal.	0.5c	0.1b	0.1b	0.1b

*Averages followed by a different letter in the same column are statistically different using DMR Test at the 5% level.

TABLE 2. Effects of three Acaricides on Predacious Mite, *Amblyseius Hibisci.* **Robinson Grove, San Diego County. Applied October 11, 1979.**

Treatment	Amount/ 100 gal. water	Average No. Predacious Mites/ Leaf Days Post-Treatment			
		7	14	20	38
Untreated check		6.7a*	4.8a	6.9a	7.6a
Wettable Sulfur 90W	8 lbs.	1.9b	3.0a	2.4b	1.5b
Thiolux® 80W	3.75 lbs.	4.5ab	3.2a	3.7b	2.1b
NR 415 oil (98% oil)	1 gal.	2.9b	2.8a	3.7b	2.9b

*Averages followed by a different letter in the same column are statistically different using DMR test at the 5% level.

Avocado Brown Mite—Aerial Application

On August 22, 1980, a helicopter application of Thiolux® at 20 lbs/A in 30 gallons water was made on an 8-10 year old Hass grove. This pesticide was evaluated for control of ABM and its effects on predacious mites. Counts of both mites were made on 50-100 randomly picked leaves prior to the application and 7 days after the application from the treated and a similar adjacent untreated grove. Results indicated a 43% reduction in ABM per leaf in the treated groves while in the untreated grove the mites increased by 32%. The number of predacious mites decreased by 97% in the Thiolux® treated grove.

The leaves from which mite counts were taken were also rated for coverage of Thiolux®. A direct relationship between coverage and ABM control was apparent. Of the leaves sampled on August 29, approximately 65% had Thiolux® present on at least half or more of the upper leaf surface. These leaves had only 20% of the surviving mites while leaves with less than one half coverage had the remaining 80%. This test could not be continued over a longer period of time because the check grove was also later treated by the grower with Thiolux®.

Western Avocado Leafroller [AmorbiaJ—Ground Application

During November and December of 1979 several insecticides were evaluated for control of late instar amorbia larvae. The test was conducted in a heavily infested 5 year old Bacon avocado grove. Results (Table 3) indicated that Lannate L®, Dylox® 80 SP and Orthene® 75 SP provided excellent control of amorbia and ranked best of all materials at both the 7 and 14 day post-treatment counts. Thuricide® HP with feeding stimulants Coax® or Gustol® when applied at high concentration, as would be by helicopter, performed better than Kryocide®8F. However, under conditions of this test, neither material provided adequate control. The water spray was applied to determine if worms were being removed from their nest by the physical action of the spray. The data indicate that this was not occurring.

Omnivorous Looper—Ground Applications

Four materials were evaluated for control of the omnivorous looper (OL) during January and February of 1980. The experiment was conducted in a 6 year old Bacon avocado grove and was directed toward late instar OL larvae.

Results (Table 4) indicate that Orthene®75 SP and Lannate D® provided excellent control. The other materials are not statistically different from the check, indicating essentially no control at either 6 or 13 days post-treatment. The 13 days post-treatment count was specifically made to determine if the activity of Kryocide® would be more pronounced over time. During this experiment such activity was not noted.

Observations of leaf damage in this grove indicated that the Reed variety sustained the most OL damage followed closely by Bacon. The Hass variety appeared to sustain only 25-50% as much damage as Reeds or Bacons.

TABLE 3. Control of Amorbia with Insecticides. Leavens Home Ranch, Ventura County. Applied November 27-29, 1979.

Treatment	Average No. Live Larvae/ Tree Sample[1] Days Post-Treatment			
	7		14	
Untreated check	9.6ab[2]	(—)[3]	9.5ab	(—)
Water spray	9.4ab	(2)	10.4a	(0)
Kryocide® 8F (8 lbs AIA) + Coax® (2 lbs/ A)	9.8a	(0)	7.8bc	(18)
Kryocide® 8F (8 lbs AIA) + Gustol® (1 lb/ A)	9.4ab	(2)	8.9ab	(6)
Thuricide® HP (10 lbs) + Gustol® (5 lbs)/ 100 gal. water	7.3bc	(24)	6.9c	(27)
Thuricide® HP (10 lbs) + Coax® (10 lbs)/ 100 gal. water	6.7c	(30)	8.2abc	(14)
Dylox® 80 SP (2 lbs AIA)	2.6d	(73)	0.3d	(97)
Orthene® 75 SP (1 lb AIA)	1.3e	(86)	0.2d	(98)
Lannate L® (1.8 lbs AIA)	0.4f	(96)	0.3d	(97)

1/ Ten nests/ tree examined each date, 6 reps of 2 trees each.

2/ Averages followed by a different letter in the same column are statistically different using DMR Test at the 5% level.

3/ Number in parentheses = percent control.

During the experiment it became evident that a large segment of the OL population was being controlled by a viral disease and parasites. Using counts made from the untreated check trees at 13 days post-treatment, 55% of the larvae and 40% of the pupae were dead from natural causes.

Another experiment directed toward early instar OL larvae was conducted in a 6 year old Bacon grove in April of 1980. Results of this test (Table 5) indicated that at high concentrations (as would be applied by helicopter) and with excellent coverage, Thuricide® HP and Kryocide® 8F will give satisfactory control of the OL. No difference was detected between the feeding stimulants Gustol® and Coax® when used with Thuricide® HP. The water spray check alone did not remove a significant number of larvae.

TABLE 4. Control of Omnivorous Looper with Insecticides. Leaven's Vista Ranch, Ventura County. Applied January 30, 1980.

Treatment	Lbs. AIA	Average No. Live Larvae/Tree Sample [1] Days Post-Treatment 6		13	
Untreated check	—	23.8a [2]	(—) [3]	10.4a	(—)
Kryocide® 8F	8.0	34.4a	(0)	11.6a	(0)
Dylox® 80 SP	2.0	26.8a	(0)	8.8a	(15)
Orthene® 75 SP	1.0	1.8b	(92)	0.2b	(98)
Lannate L®	1.8	0.6b	(97)	0.2b	(98)

1/ 30 nests/tree examined each date, 5 single tree reps.

2/ Averages followed by a different letter in the same column are statistically different using DMR test at the 5% level.

3/ Number in parentheses = percent control.

Another experiment directed toward late instar OL was conducted on 4 year old Hass trees in May of 1980. Results (Table 6) indicate that under the conditions of this study Orthene® 75 SP at either 0.5 or 1.0 Ib active ingredient per acre (AIA) will give very good control of late instar OL. Thuricide® HP and Kryocide® 96W did not give satisfactory control. However, we do not feel that this test was a fair evaluation of the latter two materials. Since the OL larvae were older and pupating, we could not conduct this experiment for an adequate length of time. Both Thuricide® and Kryocide® may have performed better had the larvae been actively feeding over a longer period of time, rather than entering the pupal stage.

From counts made in the untreated check trees it was obvious that disease and parasites were controlling a large segment of this population. On May 27 and 28, 48% of the OL larvae present were dead from natural causes.

The final ground experiment for control of mid to late instar OL larvae during 1980 was conducted on three year old Hass avocado trees. The data (Table 7) indicate that all treatments except Orthene® 75 SP at 0.25 lbs AIA gave excellent control of the OL. However, even at the lowest rate, Orthene® provided good control and could be adequate as a commercial ground application rate.

Parasitized larvae and pupae were collected from trees in all treatments as counts were made. These were held under laboratory conditions and adult parasite emergence observed. Parasite emergence did not appear to be adversely affected by any of the treatments. The most common parasite observed was a beneficial wasp, *Bracon* sp. The effect of the treatments on adult parasites in the field on the day of application is not known.

TABLE 5. Control of Omnivorous Looper with Insecticides. Leavens Vista Ranch, Ventura County. Applied April 3, 1980.

Treatment	Average No. Live Larvae/ Tree Sample[1] 12 Days Post-Treatment	% Control
Untreated check	38.8a[2]	—
Check (water spray)	39.8a	0
Thuricide®HP (10 lbs)+Gustol®(5 lbs)/100 gal. water	6.8b	82
Thuricide®HP (10 lbs)+Coax®(10 lbs)/100 gal. water	5.0b	87
Kryocide®8F (8 gals)+Coax®(10 lbs)/100 gal. water	0.7c	98

1/ Ten terminals/tree examined, six single tree reps.

2/ Averages followed by a different letter in the same column are statistically different using DMR Test at the 5% level.

TABLE 6. Control of Omnivorous Looper with Insecticides. Gray-Stropes Grove, Highland Valley, San Diego County. Applied May 19, 1980.

Treatment	AIA [Lbs]	Average No. Live Larvae/ Tree Sample[1] 8-9 Days Post-Treatment	% Control
Untreated Check	—	8.0a[2]	—
Thuricide® HP + Gustol®	1.5 1.0	10.7a	0
Kryocide® 96W + Gustol®	20.0 1.0	6.5a	19
Orthene® 75 SP	1.0	0.5b	94
Orthene® 75 SP	0.5	1.0b	88

1/ Sixty nests/tree examined, six single tree reps.

2/ Averages followed by a different letter in the same column are statistically different using DMR test at the 5% level.

Data from the untreated check trees in this experiment indicate that on July 17, 32% of the OL larvae were dead from natural causes. A follow up count on July 31 showed 94% of the insects (larvae and pupae) had died naturally.

TABLE 7. Control of Omnivorous Looper with Insecticides. Gillett Grove, San Diego County. Applied July 9, 1980.

Treatment	Average No. Live Larvae/Tree Sample 1/	
	8 Days Post-Treatment	% Control
Untreated check	48.2a [2]	—
Orthene® 75 SP, 0.25 lbs. AIA	8.6b	82
Kryocide® 96W, 20 lbs. AIA	2.6bc	95
Orthene® 75 SP, 0.5 lbs. AIA	1.2c	98
Kryocide® 96W, 12 lbs./20 gals. water	0.4c	99
Orthene® 75 SP, 1 lb. AIA	0.0c	100

1/ 40 nests/tree examined, five single tree reps.

2/ Averages followed by a different letter in the same column are statistically different using DMR test at the 5% level.

Omnivorous Looper—Aerial Applications

A helicopter application of Thuricide® HPC was applied to 7 year old Hass avocado trees on the Belknap Grove, Valley Center, for control of early instar OL larvae on July 3, 1980. The application consisted of 3 qts. of Thuricide® HPC, 1.25 Ibs brown sugar, and 12.5 Ibs zinc sulfate in 20 gallons water per acre. Pre-treatment counts were made on ten 6-inch long leaf terminals/tree. At 15 days post-treatment a similar number of 18-inch terminals were examined for all stages of OL larvae. Twelve trees were examined on both dates in the treated grove and a similar number in an adjacent untreated grove for comparison.

Results of this test did not indicate any increase in mortality in the treated grove over that naturally occurring in the check grove. The pre-treatment count in the treated grove was 24.3 larvae as opposed to 35.2 larvae per tree sample in the untreated grove. At 15 days post-treatment the number of larvae per tree sample in the treated grove had dropped to 7.8, a 68% reduction. However, the number per tree in the untreated grove had dropped to 7.0, an 80% reduction.

These data indicate that Thuricide® HPC when applied as discussed above does not provide satisfactory control of the OL on avocados. The effect the addition of zinc sulfate had on the effectiveness of Thuricide® HPC is not known. Since the pesticide is highly selective and could fit into an avocado IPM program, the authors feel additional evaluations of this product should be conducted before definite conclusions are drawn.

Thuricide® HPC has been bioassayed at the equivalent of 0.5 gallon per acre under laboratory conditions and results show it to be 85% effective in killing middle age (third instar) OL larvae. (Personal communication, Federici and Johnson, 1980.) We feel the reason for its ineffectiveness in the field may be that coverage, when applied by air, is far from adequate. Therefore, the probability of worms consuming it is very low.

Three different helicopter applications of Lannate L® were evaluated during 1980 for control of OL. One hundred twenty to two hundred OL nests were examined per test, prior to the application, and a similar number examined 2-8 days post-treatment. Results (Table 8) indicate satisfactory control was obtained. Follow up counts made in two groves at 16 and 20 days post-treatment indicated that this insecticide apparently did not eliminate all of the beneficial insects. Those OL larvae remaining after the Lannate® treatment were apparently adequately controlled by natural enemies (Table 8).

We believe that many of the parasites of the OL are protected from the insecticide since they are enclosed within the OL nests as eggs, larvae or pupae. Since Lannate® completely degrades in a matter of hours, those adult parasites emerging after it has degraded are not affected and can readily parasitize and reproduce on the remaining OL larvae. However, those OL parasites and predators which are exposed to Lannate® during the application will probably be killed. The effect Lannate® may have on other beneficial insect predators or parasites is not known.

Data collected before and after Lannate® applications indicate that predacious mites and other beneficials associated with the ABM are almost completely eliminated by this insecticide. Predacious mite counts remained very low for several months after the applications. Other beneficials did reappear but later than would be expected in an untreated grove. (Personal communication, McMurtry, *et al.*, 1980.)

TABLE 8. Efficacy of Lannate L Applied by Helicopter at 1 Lb. AIA for Control of the Omnivorous Looper. San Diego County. July 1980.

Test Grove	Time of Day	Percent Mortality	
Stout (Hass)	a.m.	66 (2)*	95 (20)
Strong (Hass)	a.m.	70 (8)	94 (16)
Olson (Zutano)	p.m.	78 (3)	

*Number in parentheses indicates days post-treatment.

SUMMARY

Avocado Brown Mite Control

a. Narrow Range (NR 415) spray oil provided good control while Thiolux® and wettable sulfur provided moderate to poor control of the ABM. All treatments reduced the number of predacious mites.

b. A helicopter application of Thiolux®provided fair control of ABM, but also substantially reduced the number of predacious mites.

Amorbia Control

Lannate L®, Dylox® 80 SP and Orthene® 75 SP provided very good control. *Bacillus thuringiensis* (Thuricide® HP) at helicopter concentration rates did not adequately control amorbia larvae.

Omnivorous Looper Control

a. Ground applications of Thuricide® HP highly concentrated (as would be applied by helicopter) satisfactorily controlled OL larvae.

b. Results of one experiment strongly suggest that helicopter applications of *Bacillus thuringiensis* (Thuricide® HPC) are not effective in controlling the OL.

c. Kryocide®96W when applied by ground, at a helicopter concentration rate or when applied by ground at 20 Ibs AIA, provides very good control of the OL larvae.

d. Dylox®80 SP did not control OL larvae in these experiments.

e. Orthene®75 SP provided excellent to very good control of OL larvae at all rates tested.

f. Lannate L® when applied by ground controlled 97-98% of the OL larvae and when applied by air provided 66-78% control. Predacious mites and other beneficials associated with the ABM were almost completely eliminated by aerial applications of Lannate L®.

Feeding Stimulants

No difference was detected between Gustol® or Coax® when used with either Kryocide® or Thuricide® for control of amorbia or OL larvae. The benefit from using either feeding stimulant was not determined in these experiments.

Phytotoxicity

None detected with any of the pesticides evaluated.

DISCUSSION

Until this project was funded by the California Avocado Advisory Board, the only avocado pest seriously studied was the avocado brown mite. Research on other pests was very limited. This means that there is only a limited amount of information available on which to build an IPM program. The biology and ecology of the pests and their enemies are not well understood, a valid sampling method is not readily available, and very little information is available on the economic threshold or pest infestation level at which a pesticide application may be required. Thus, it is currently difficult for growers and fieldmen to make sound control decisions.

These pesticide experiments are just one aspect of developing an IPM program for California avocados. The emphasis in this work has been and will continue to be on selectivity. Pesticides which are effective, not phytotoxic, and have minimal adverse effects on the beneficial complex are preferred for use in avocado IPM.

In addition to the pesticide experiments, other ongoing research is being conducted to fill information gaps. Such research includes biology studies, population monitoring studies and sex attractant pheromone work. We are working closely with other researchers in the field of biological control to incorporate all information into an IPM program.

In the interim we suggest that those making pest management decisions seriously consider the following:

1. Realize that beneficial organisms and certain weather conditions normally keep avocado pests under control. Wait as long as possible to see if your pest "problem" will be controlled naturally. Be observant—check your groves frequently for both pests and beneficial parasites, predators or pathogens.

2. Treat only when necessary. Treat when the pesticide will be most effective. Treat only the infected areas. There is no question that in any IPM program pesticides can and should be used to prevent a financial loss.

3. If a decision has been made to use a pesticide, use one that is selective or which can be used selectively. Use the pesticides at their lowest effective rate.

4. Keep abreast of current research findings.

5. When in doubt, get professional assistance.

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