ALMOND BOARD OF CALIFORNIA
ANNUAL REPORT - 1989

Project No. 89-C12 - Insect and Mite Research

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Objectives:

1) Provide traps and lures to Cooperative Extension Advisors to monitor population levels of navel orangeworm peach twig borer, and oriental fruit moth on an ongoing basis. This information will be summarized and used to interpret and validate phenology models on almonds.

2. Validation of navel orangeworm phenology and initiation of new control research.

3. Validation of mite management software.

4. Initiate studies to identify a navel orangeworm pheromone.

Results:

Population monitoring. Pheromone traps and lures were provided to all Cooperative Extension Advisors who requested them. Six Farm Advisors received a total of 28 NOW traps and bait, 178 wing-style traps, 336 trap liners, 510 peach twig borer lures, and 80 oriental fruit moth lures.

The data obtained by the Advisors will be summarized using the UC Trap Counts program, and will become part of our database on the phenology of these pests.

Navel Orangeworm Phenology and Control Studies. In 1987, I compared various phenology models proposed for predicting the development of navel orangeworm. The results presented in my 1987 Annual Report showed no significant difference between methods in their ability to predict the flight of navel orangeworm, although all had considerable spread in the predictions. In 1988, a program was developed to permit the direct use of the developmental rate data developed by John Sanderson. In 1989, a data set was obtained and used to validate the program. The results showing predicted versus observed dates of the initiation of the third navel orangeworm flight are provided on Figure 1. The program again seemed to predict this event adequately for field use.

Dissemination of the program is quite complicated as a users manual must be developed and the program approved. Although I indicated this as a goal in 1989, I have been unable to write a manual or to pursue the approval process. In the end, I wonder if the development of this program is better than simply using degree-days as we currently do for other pests such as peach twig borer or San Jose Scale. All of our validation work seems to indicate that there is not really a significant difference. The development of the nonlinear model is really an artifact of prior research to develop such a model. I will continue to work with the nonlinear model and will make one of my goals in the next year developing the users manual. Individuals wishing to use a degree-day linear model for prediction can use the handout I developed for the l989 Almond Board Research Conference in Modesto (Figure 2). The use of 55F and 94F lower and upper thresholds with a mean generation time of 1025DD and a second 1025DD for the seconf flight seems to predict the start of the third flight quite well.

Food safety as manifested in the pesticide residue debate and regulatory issues such as proposed extensions of harvest intervals or outright bans on product uses or registrations have brought our traditional approaches to pest control into question for the long term. It is no longer possible to assume that chemical treatments for navel orangeworm such as azinphosmethyl will be available in the future. Therefore in 1989, we began to explore the possibility of using Bacillus thuringiensis (B.t.) for control. Studies on microbial control were sponsored by the Almond Board as long as 15 years ago. However, these materials were not pursued because they were not considered effective. Of course, cultural controls such as sanitation and early harvest were not practiced to a great extent, and therefore populations being treated in test plots were likely more extensive than we have at present. Also, controls such as azinphosmethyl, carbaryl permethrin (e.g. Table 1), etc. have not proven particularly effective either, usually providing less than 50% control even when properly applied. B.t. is known to kill navel orangeworms in laboratory situations, but navel orangeworm is considered only moderately suscetible when compared to B.t. efficacy against other Lepidoptera.

In 1989, 2 field trials were conducted using the registered B.t. product Javelin. One field trial was in Butte County with Joe Connell and another in Kern County with Walt Bentley. Treatments consisted of Guthion at 2 lb. AI per acre at hullsplit, Javelin at 1 lb. AI per acre at hullsplit, Javelin at 1 lb. AI per acre plus Guthion at 0.25 lb. AI per acre at hullsplit, an untreated control, Javelin at 1 lb. AI per acre at hullsplit and again 2 weeks later, and the Javelin plus Guthion treatment at hullsplit and Javelin at 1 lb. AI per acre 2 weeks later (Kern Co. plot only). Plot size in both trials was about 0.5 acres per treatment replicate. There were 4 replicates of each treatment in each trial. At harvest, 1000 nuts were taken from the the center of each treatment and returned to Davis where they were held in cold storage until cracking. Data were analyzed using analysis of variance and Duncan's multiple range test.

The results of this study are presented on Tables 2 and 3. The Javelin treatment applied at hullsplit and again at an interval of 2 weeks was the best treatment in the Butte County trial (Table 2), however none of the pesticide treatments (Javelin, Guthion, or various combinations) were significantly different from one another. All of the treatments performed somewhat better than no treatment, and control levels ranged from 44% to 30%. The traditional hullsplit Guthion treatment only afforded 32% control. Joe Connell who applied this plot said that the application was perhaps a little later than optimum. It is possible that Javelin applications delayed a bit provide better control than immediately upon hullsplit. It was interesting to note that the addition of a low rate of Guthion to the B.t. material did not provide synergistic action. Guthion gave the highest level of control in the Kern County trial (Table 3). None of the treatments applied in this trial were significantly different from the untreated control. Control levels did not exceed 29% for any of the treatments. The Javelin treatment applied at hullsplit and again at an interval of 2 weeks was the best of the treatments that included a B.t. material. Again, the addition of Guthion to the B.t. material did not provide evidence of synergism.

Our results confirm the observations of many individuals that no currently registered insecticide provides adequate control of navel orangeworm. The only effective control we can recommend is good sanitation (mummy removal) and early harvest.

Mite Management Program. Development of a computer program for predicting development of spider mite and predator populations, and for relating presence-absence or brush and count monitoring to mite-day thresholds was initiated in September, 1988.

The development of such a program seemed useful to address the conflict in sampling techniques and treatment thresholds. Considerable progress was made by M.A.Hoy who developed decision rules based upon brushing and counting mites from leaf samples and using treatment thresholds based upon accumulated spider mite days. A simpler sampling plan and fixed treatment threshold was developed by L.T. Wilson, M.A. Hoy, F.G. Zalom, W.W. Barnett and J.M. Smilanick. who developed a presence - absence sampling scheme in which a number of leaves are sampled, and the fraction of leaves containing spider mites and the fraction containing predacious mites are both recorded. Wilson et al. also found that complete control can be reliably obtained if the fraction of leaves containing predacious mites is at least as great as the fraction containing spider mites.

The model is based on the observation that if the fraction of leaves containing spider mites and the fraction containing predacious mites are plotted as functions of time then both of these curves are approximately logistic, or S - shaped. The model therefore consists of fitting a logistic curve to the two data sets using least squares regression, extrapolating the curves in time, and determining whether these curves intersect, and if so, where they intersect. If the two curves intersect below the economic threshold then the predators can be expected to control the spider mites and no pesticide is needed. If the two curves intersect at a point above the economic threshold then depending on the projected level of infestation when they intersect a reduced level of pesticide can be determined that will provide sufficient control to permit the predators to achieve complete control. Either binomial sampling or actual spider mite counts can be used for projections.

Figures 3 through 6 illustrate the model. Tthe user inputs spider mite and predator counts. These values are used to calculate population curves for both the spider mites and the predator mites (Figure 6). If insufficient data is available for projecting the populations, no treatment decision is made and more samples must be taken. It the curves do not intersect, a set of decision rules are invoked as illustrated in Figure 4. If the curves intersect, it must be determined if the intersection will occur above or below a treatment threshold (based on spider mite days or a fixed threshold if specified). If the intersection is below the threshold, no treatment is recommended and continued sampling is required. If the curves intersect above a treatment threshold, the predator mite to spider mite ratio becomes important, and treatment decision are based upon the most current ratio.

This scheme is implemented using the CALEX expert system, a computer program developed by R.E. Plant. This program provides a user friendly framework on which to implement the algorithm developed using this model. Development of the computer model and expert system on CALEX Version 2.0 rulebase is now complete. The system will be transferred to CALEX Version 3.0 in the spring of 1990. Data sets have been collected from almond orchards in 3 counties. These data sets consist of proportion of occupied leaves for spider mites and predator mites throughout the season. The model will be tested against these data sets by using early values of the data to construct the regression curves, projecting these curves to future time values, and comparing the projected data values with those actually obtained.

Navel Orangeworm Pheromones. Several researchers have worked on identification of a pheromone for the navel orangeworm. The pheromone that has been identified is not effective for attracting male moths in the field. Better identification of the components of the navel orangeworm pheromone could lead to a useful tool in monitoring, particularly after hullsplit. It might also have long term significance in control via mating disruption.

In 1989, we established a colony of navel orangeworm at Davis, and are supplying Dr. Les McDonough with pupae from this colony. We are also supplying freshly collected worms from field samples for comparison. We ship the specimens via Federal Express to the quarantine facility of the USDA Tree Fruit Lab at Yakima, Washington at intervals of approximately 2 weeks. Dr. McDonough tests extracts from the female moths on male moths emerged from the pupae we send him in a flight tunnel. Field testing of the extracts will be conducted in California when he feels that his laboratory results would indicate potential for field success. Although the time of such a trial is impossible to determine, we are prepared to conduct the trial in the next season.

Figure 1

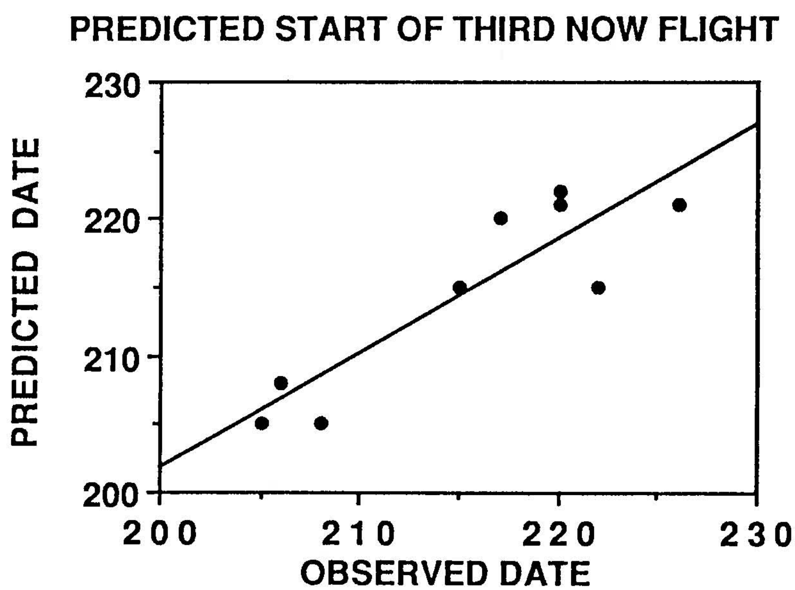

PREDICTED START OF THIRD NOW FLIGHT
PREDICTED DATE
230
220
210
200
200
210
220
230
OBSERVED DATE

Figure 2

NAVEL ORANGEWORM DEGREE-DAYS

Navel orangeworm populations can be monitored in several ways. The easiest method at this time involves monitoring oviposition by females using black egg traps fill with almond presscake fortified with almond oil.

The most useful application of navel orangeworm monitoring is to determine the beginning of emergence of the second generation adults, which is the third flight of moths. Harvesting almonds before this flight or as early in this third flight as possible is an excellent strategy to reduce damage. Failure to harvest early in relation to this flight has been demonstrated to result in ever-increasing damage.

Degree-days can be accumulated using a horizontal upper developmental cutoff or a vertical upper developmental cutoff. The horizontal cutoff assumes that development occurs at a constant rate once the upper threshold is reached. This is the same method currently used for such pests as peach twig borer and oriental fruit moth. The vertical cutoff assumes that development stops when temperatures reach or exceed the upper threshold. Both methods have been validated with existing trapping data, and tables for hand calculation are presented on the reverse of this handout.

The horizontal method uses a lower developmental threshold of 55°F and an upper developmental threshold of 94°F with a horizontal upper developmental threshold cutoff. Mean developmental time for navel orangeworm on mummy nuts is 1025 degree-days, and on new crop nuts 692 degree-days. Mean egg hatch is at 100 degree-days. The start of the first generation flight (second observed flight) is 1025 degree-days after the spring biofix, the first date at which eggs are consistently observed on the traps. The important start of the second generation flight (third observed flight) is at 1025 degree-days after the start of the first generation flight (second observed flight). Nonpareil trees should be shaken as soon as possible after this date.

Figure 3

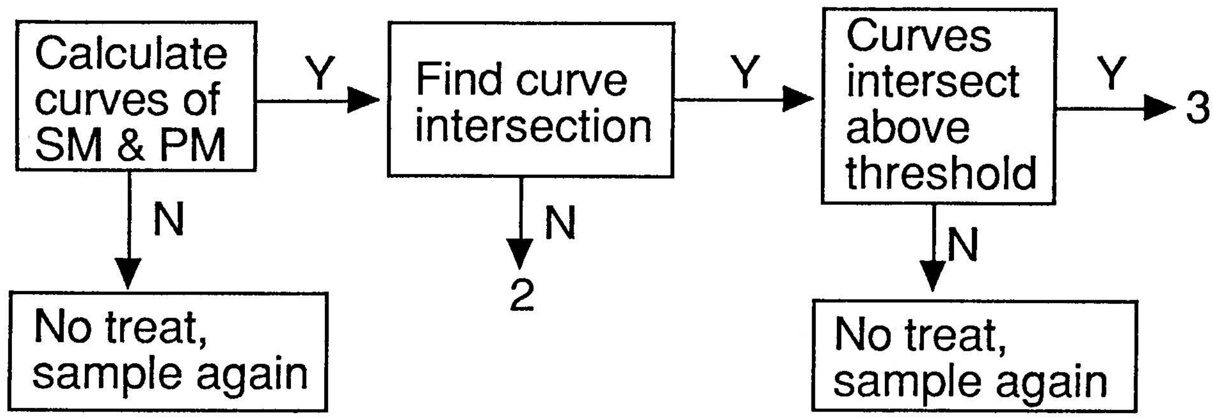

Calculate curves of SM & PM
Y
N
No treat, sample again
Find curve intersection
Y
N
2
Curves intersect above threshold
Y
3
N
No treat, sample again

Figure 4

2. IF CURVES DO NOT INTERSECT:

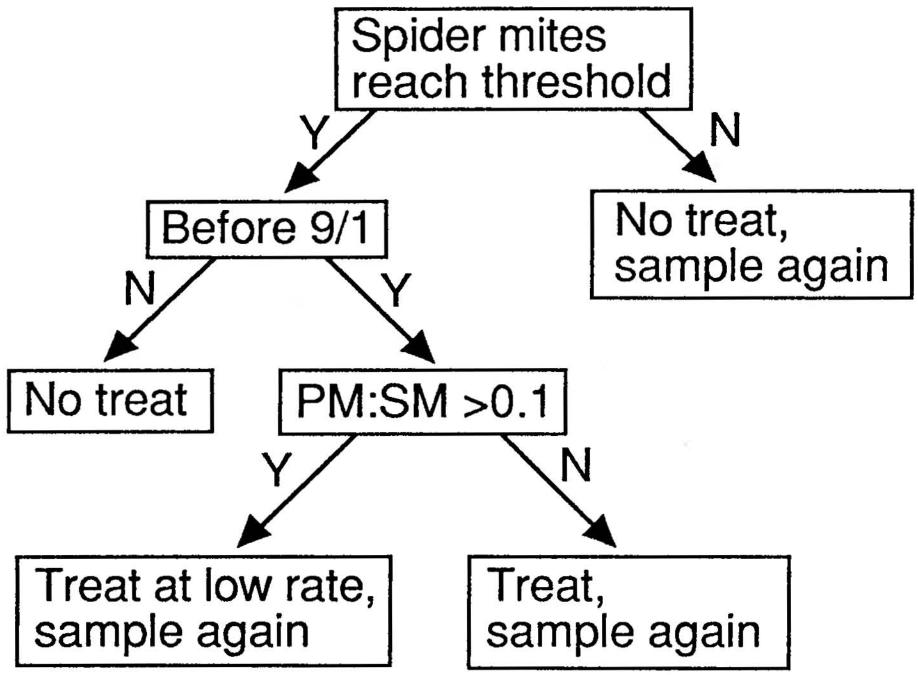
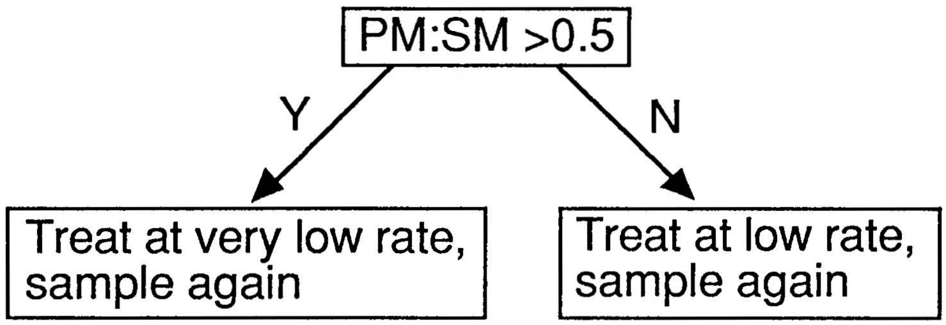


Figure 5

3. IF CURVES INTERSECT ABOVE THRESHOLD:



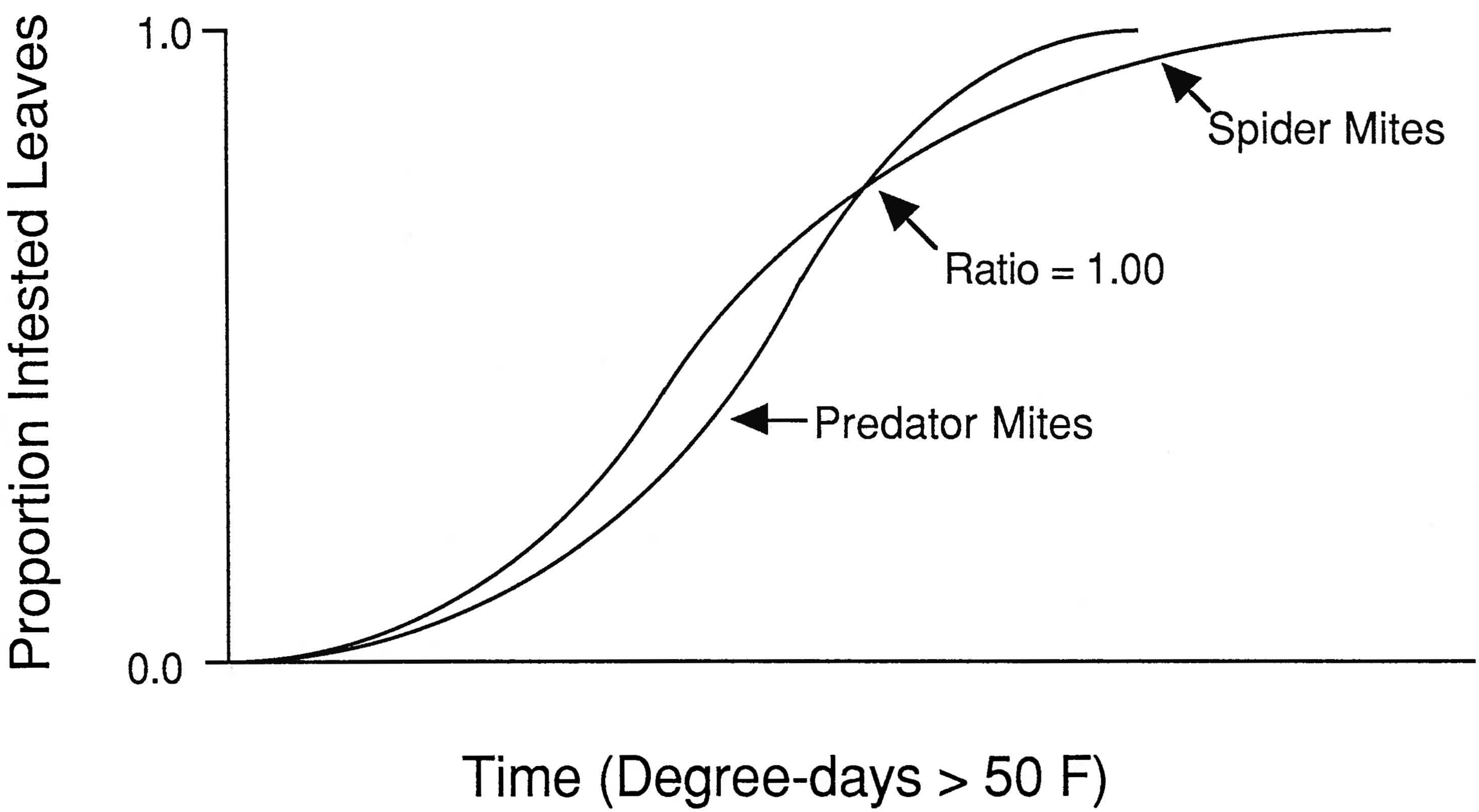

1.0
0.0
Proportion Infested Leaves
Spider Mites
Ratio = 1.00
Predator Mites
Time (Degree-days > 50 F)

Figure 6

Table 1

NAVEL ORANGEWORM
HULL SPLIT SPRAY

TREATMENT	AI/ACRE	% DAMAGE
Permethrin	0.2	4.2 a
Guthion	2.0	5.1 ab
Permethrin	0.1	5.2 ab
Untreated	--	8.9 c

Table 2

NAVEL ORANGEWORM - BUTTE COUNTY
HULL SPLIT SPRAY (4 REPS.)

	Damage (%)	
Treatment	Mean	SD
Javelin (2x)	4.38	1.45 a
Javelin (1x)	4.56	0.90 a
Guthion	5.38	2.32 ab
(Javelin+Guthion)+Javelin	5.38	1.03 ab
Javelin+Guthion	5.50	0.71 a
Untreated	7.81	2.44 b

Table 3

NAVEL ORANGEWORM - KERN COUNTY
HULL SPLIT SPRAY (4 REPS.)

	Damage (%)	
Treatment	Mean	SD
Guthion	4.94	1.16 a
Javelin (2x)	5.00	1.51 a
Javelin (1x)	5.81	1.84 a
Untreated	7.00	3.24 a
Javelin+Guthion (1x)	7.81	2.35 a

17TH ANNUAL ALMOND RESEARCH CONFERENCE, DECEMBER 5, 1989, MODESTO

Project No. 89-C12 - Insect and Mite Research

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Cooperating Personnel: Various Cooperative Extension Advisors,
Dr. L. M. McDonough

Objectives: (1) Continue to supply cooperating Farm Advisors with lures and traps for monitoring, (2) initiate implementation of navel orangeworm phenology models, (3) field validate and demonstrate mite management software, and (4) initiate studies of navel orangeworm pheromone.

Interpretive Summary: Once again in 1989, traps and bait for navel orangeworm, and traps and pheromone lures for peach twig borer, San Jose scale or oriental fruit moth were purchased for Cooperative Extension farm advisors working on almonds who requested them. Data obtained from their effort will become part of our database on the phenology of these pests which we continue to assemble and which has proven useful historically in various research projects.

Degree-day phenology models for navel orangeworm appear to predict their generation time quite well. A handout explaining the use of degree-days for navel orangeworm will be available at our table during the conference. A microcomputer program which uses the navel orangeworm developmental curve directly instead of approximating development with degree-days has been developed. A microcomputer program to track spider mite and predator mite population development, and to predict when and if treatment thresholds would be reached has been under development. This program fits a modified logistic curve to field data, and predicts the point at which the predator and prey curves intersect. If the intersection is projected to be above either a "proportion infested leaves" or "spider mite days" treatment threshold as specified, a treatment is recommended at the earliest possible date. Similarly, a treatment is recommended if predator populations are insufficient to intersect the spider mite population curve and the spider mite populations are projected to reach treatable levels. No treatment is recommended if the curves intersect below a treatment threshold.

Dr. Les McDonough of the USDA Tree Fruit Laboratory at Yakima, Washington, is working with us to identify a pheromone for the navel orangeworm. We began to ship navel orangeworm pupae from a colony we have established in our laboratory, and field collected larvae to Dr. McDonough this past summer. He will send us material to field test. Navel orangeworm is a quarantined pest in Washington State, and we have obtained all permits necessary to continue these shipments.