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Project No. 83-D10: Navel Orangeworm, Mite and Insect Research
Insecticides and Mite Studies

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Objectives: (1) To develop optimum use of insecticides for control of navel orangeworm in almond orchards, including the development of new compounds for registration on almond; (2) To develop new miticides for control of mites on almond; (3) To continue development of data for the NOW population model; (4) To investigate effects of different species of mites (greenhouse studies); (5) To investigate the practical role of mite predators in the southern San Joaquin Valley and that of beneficials attacking NOW (on other funds); (6) To prepare articles summarizing our investigations.

Interpretative Summary: (1) The 1983 Insecticide Performance experiment failed to demonstrate differences in navel orangeworm control between 3 experimental insecticides, a Guthion standard, and an unsprayed check. This result was due to an extremely low level of navel orangeworm damage among all the treatments. (2) The upper developmental threshold temperature for navel orangeworm pupae lies between 95° and 100°F, as determined by a laboratory experiment. (3) Based on the results of experiments conducted in 1982 and 1983, an average of 1125 degree-days are required for navel orangeworm development on mummy almonds in the field. The importance of using a 55°F lower developmental threshold and a 94°F upper developmental threshold with a vertical cutoff is demonstrated. (4) A laboratory study was conducted to determine the fraction of the total degree-day requirement for navel orangeworm development (from first instar to adult) which is required for each of the larval instars. The results of a field study of navel orangeworm development on new-crop almonds appeared to confirm the results of the laboratory study. (5) A study using blacklight traps was conducted in order to provide an additional year of data to test the validity of a thermal summation model of navel orangeworm development on new-crop almonds. The results of this study, in which degree-days were accumulated between the initiation of hullsplit and peak blacklight trap catch, neither confirm nor invalidate this degree-day model. (6) Mummies infested with navel orangeworm and placed in cages may provide a constant source of larval hosts for the parasites of the navel orangeworm, if the moths can develop and reproduce on these caged mummies. It was found that navel orangeworm individuals were able to develop and reproduce on caged mummy almonds in the field. However, under summer conditions, they were not able to substantially increase their numbers within the cages. (7) Larval infestation by peach twig borer was found to be significantly higher in "Nonpareil" nuts from the upper tree half vs. the lower half. (8) The preferred density for peach twig borer pheromone traps appears to be no more than one trap per acre, i.e. do not crowd traps closer than one per acre. (9) This year's acaricide trial was not able to statistically detect any material in being better able to control spider mites when compared to the Omite standard. Mavrik 2EC, NC-21314 50SC, and 415 NR oil were sparing of the predatory sixspotted thrips. (10) Ten-year-old

Nonpareil almond trees, sprayed with treatments containing permethrin (Ambush plus Omite, Ambush alone) at hullsplit in 1982 developed significantly higher spider mite populations in early spring 1983 than did trees sprayed with Guthion plus Omite, or unsprayed trees. (11) Feeding injury by the Pacific spider mite resulted in significantly lower photosynthetic rates when compared to the citrus red mite.

Publications 1983:

Engle, C. E., and M. M. Barnes. 1983. Developmental threshold temperature and heat unit accumulation required for egg hatch of navel orangeworm (Lepidoptera: Pyralidae). Environ. Entomol. 12(4): 1215-1217.

Engle, C. E., and M. M. Barnes. 1983. Cultural control of navel orangeworm in almolnds orchards, Calif. Agric. 37(9, 10)19

Investigations on Navel Orangeworm, Mites and Peach Twig Borer in Almond Orchards 1983

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Trial of Experimental Insecticides for the Control of the Navel Orangeworm on Almonds at Hullsplit

J. F. Sanderson, M. M. Barnes, and E. F. Laird

As part of a continuing effort to develop new insecticides for the control of the navel orangeworm on almonds, an experiment was conducted in Kern County, CA to determine the efficacy of 3 experimental insecticides applied to almonds at the initiation of hullsplit. The efficacies of these compounds were compared to that of Guthion 50WP as well as an unsprayed check.

Methods and Materials

A portion of an orchard located near Richgrove, CA was selected for this experiment and consisted of 16-year-old, sprinkler-irrigated trees planted in a quincunx planting scheme. Two rows of Nonpareil variety trees alternated with single rows of either the Merced or NePlus variety. Only Nonpareil trees were used in this experiment.

The experimental compounds tested were FMC 54800 2EC (applied at 2 rates), SC-1069 35WP (Stauffer), and S-3206 (Chevron-Sumitomo). Guthion 50WP was used as a standard. The 5 spray treatments plus an unsprayed check were included in each of 10 blocks, using 6 single-tree replicates in each block.

Trees were sprayed at the initiation of hullsplit, based on hullsplit surveys which included nuts from both the top and bottom of the trees. At the time of application (7/7/83), 6% of the nuts sampled in the tops of the trees were hullsplit. No hullsplit nuts were found at eye level.

Sprays were applied using a handgun with a #8 disc at 400-450 psi. The trees were sprayed to run-off with an average of 12 gallons of dilute spray per tree, resulting in an application rate of ca. 800 gallons per acre. Observations for possible phytotoxicity were made at 7 and 14 days post-spray.

At harvest (8/23/83), all nuts were shaken from each tree. Samples of 300 nuts per tree were then collected into bags, taken to the laboratory, and stored at 40°F until examined for navel orangeworm damage.

Results

Table 1 presents the average percent of the total number of almonds per sample for each treatment which were damaged by navel orangeworm. No statistically significant differences in percent damage occurred between any of the treatments, including the unsprayed check. Obviously, navel orangeworm damage was extremely low in all samples. Although a navel orangeworm population was present in this orchard (oviposition on egg traps in May, 1983 was obvious), there were very few mummies present in May and June to support a large population. The same was true for all the orchards which were inspected in June as possible candidates for the location of this experiment. The scarcity of mummies in May and June probably accounts for the extremely low damage levels of all samples at harvest. No obvious phytotoxicity was observed for any treatment at 7 or 14 days post-spray.

Table 1. Results of experiment on the efficacy of insecticides used for navel orangeworm control on Nonpareil almonds, Kern Co., 1983.

Treatment	Formulation	Lb ai/acre[a/]	Average % damage at harvest[b/]
3. FMC 54800	2.0EC	0.1	0.33
4. Guthion	50WP	2.0	0.41
5. S-3206	2.4EC	0.2	0.47
2. FMC 54800	2.0EC	0.06	0.56
1. SC-1069	35WP	2.0	0.80
6. Check	-	-	0.57

[a/] Applied (7/7/83) by handgun at 6% hullsplit in treetops; 800 gal per acre; 10 blocks of single-tree replicates.

[b/] Based on 300-nut samples taken from each tree; harvested on 8/23/83.

INVESTIGATION OF THE UPPER DEVELOPMENTAL THRESHOLD TEMPERATURE FOR NAVEL ORANGEWORM PUPAE

J. P. Sanderson, R. R. Youngman, and M. M. Barnes

W. S. Seaman and M. M. Barnes developed a thermal summation model for navel orangeworm development on new-crop almonds in the field (1982 Annual Report). This model requires the use of a 94°F upper developmental threshold with a vertical cutoff. The addition of an upper threshold greatly improved the accuracy of the model. Therefore, it was decided to try to determine the upper developmental threshold temperature for various stages of the navel orangeworm in the laboratory. This should be done in order to biologically confirm the use of an upper threshold in the heat summation model. The present experiment was conducted to explore the upper developmental threshold temperature for navel orangeworm pupae in the laboratory.

Methods and Materials

Navel orangeworm larvae were reared at 80°F on a diet of red wheat bean, glycerin, and honey. Sometime after reaching the sixth instar, the larvae began spinning cocoons in preparation for pupation. The cocoons were checked every 6 hours for pupation. The cocoons containing newly-pupated individuals were then placed in small plastic vials which were capped with screened lids to allow airflow. Twenty-four of these vials were then placed in each of 6 constant temperature cabinets set at either 75,

80, 85, 90, 95, or 100°F. The relative humidity in the cabinets ranged from 50-90%. The pupae were observed every 3 hours for adult emergence.

Results and Discussion

The average duration of development as well as the rate of development (% development per hour) is plotted for each temperature in Figure 1. Regressing the rate of development on temperature produces a regression equation of $y = -0.697 + 0.0153X$, and an r^2 value of 0.92. The average heat-unit accumulation over all temperatures was 4950 degree-hours.

No adults emerged from the pupae held at 100°F, although the pupae were left in the cabinet for nearly 3 weeks. The highest rate of development occurred at 95°F.

The upper developmental threshold temperature for an organism can be roughly defined as the temperature at which the developmental rate begins to decline. This is not the same as thermal death. Since the maximum developmental rate occurred at 95°F, and thermal death occurred at 100°F, then the upper developmental threshold for navel orangeworm pupae must lie between 95 and 100°F.

In the future, we will attempt to establish the upper developmental threshold temperature for the egg and pupal stages, and possibly one of the larval instars.

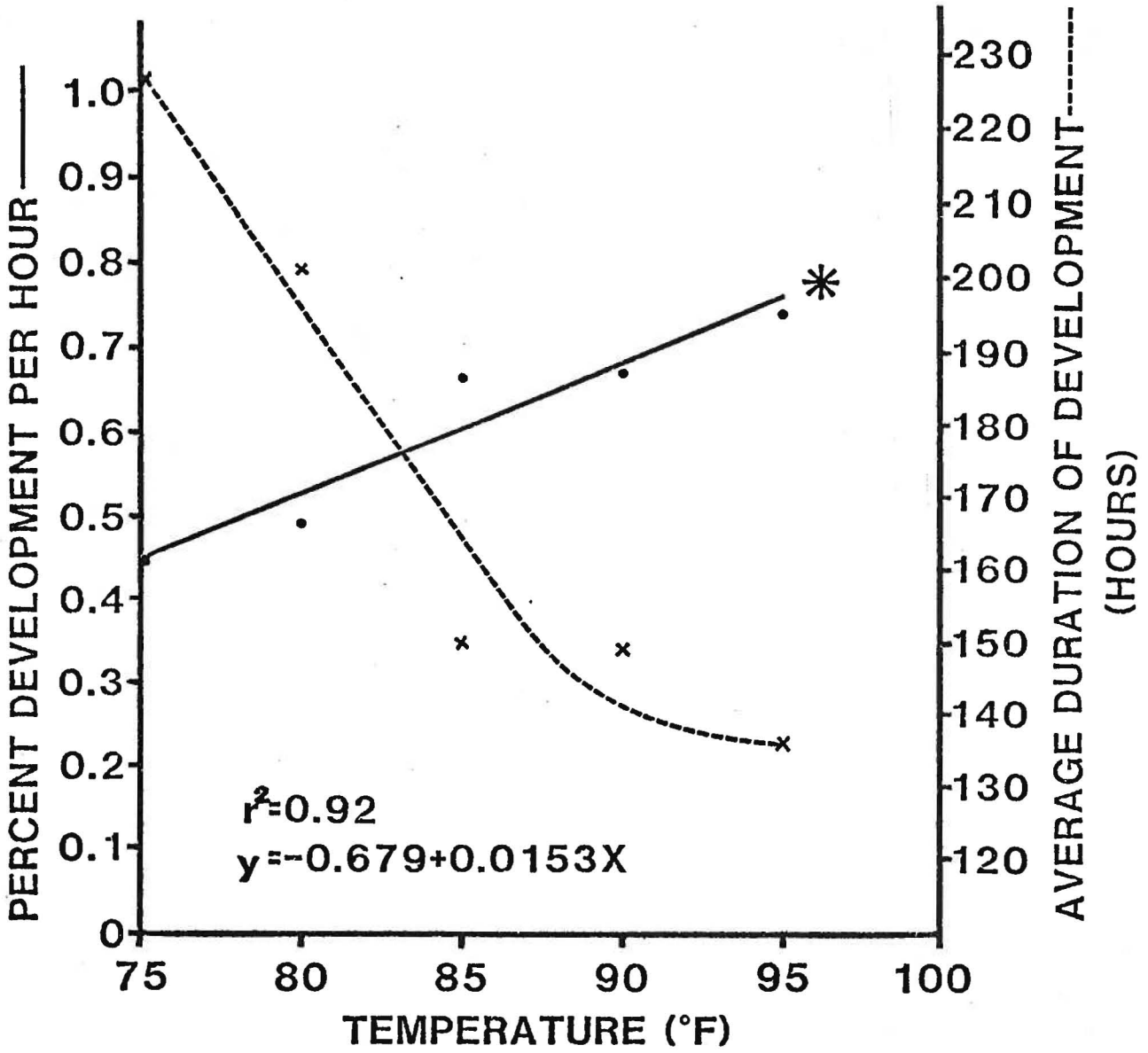

Fig. 1. Average duration of development and developmental rate of navel orangeworm pupae at 6 temperatures. Asterisk denotes no moths emerged from pupae held at 100°F.

THERMAL SUMMATION FOR NAVEL ORANGEWORM DEVELOPMENT ON MUMMY ALMONDS IN THE FIELD

J. P. Sanderson and M. M. Barnes

Several researchers have demonstrated that the time required for navel orangeworm development can vary depending on the rearing diet. Development is slower on diets with a low moisture content. Since mummy almonds have a lower moisture content in both hulls and nut meats than do new-crop nuts, it might be expected that development may take longer on mummy nuts than on new-crop nuts. Indeed, previous work by W. S. Seaman and M. M. Barnes appearing in the 1982 Annual Report showed that an average of 1122 degree-days were required for navel orangeworm development from egg to adult on mummy almonds in the field, compared to an average of 766 degree-days for development on new-crop nuts.

Since the experiment of Seaman and Barnes regarding thermal summation on mummy almonds was only conducted once, a similar experiment was conducted in 1983 in order to validate their results.

The results of these experiments concerning thermal summation on mummy nuts as well as new-crop nuts are vital to the development of predictive models, which in turn may lead to more effective control.

Methods and Materials

Nonpareil mummies were poled onto tarps from trees in a Kern County almond orchard in February, 1983, brought back to the laboratory at UCR, and stored at 40°F. Uninfested mummies were separated from infested ones. Newly-hatched first-instar larvae, which were produced by wild moths which had recently emerged from another group of mummy nuts, were used to inoculate the uninfested mummies. Holes were punched in the mummies with a dissecting needle, and 3 or 4 larvae were placed in the holes of each nut on 18 May. Twenty of these nuts were placed in each of 10 cages.

The cages were constructed out of round, half-gallon ice cream containers, including lids. The bottoms of the containers were removed, and 2 large 4 X 8 in. windows were cut out of opposite sides of each container. Wire mesh screen was used to replace the sections of the containers which were removed. The screen provided good airflow through the cage while preventing the escape of emerging moths. Another layer of screen was placed 1 in. above the bottom of the container. This second layer of screen suspended the mummies above the bottom of the cage so that wild moths could not directly oviposit on the caged mummies. A wire was looped through the cage near the top and used to hang the cage from a tree branch.

After the 20 inoculated mummies were added to each of the 10 cages, the cages were then placed in a 10-year-old almond orchard located ca. 4 mi. north of Shafter, CA, on 19 May. Five cages were hung in each of 2 rows of Nonpareil trees. The 2 rows were located in widely separated areas of the orchard. The cages were spaced 9 trees apart along each row, and were hung in the north side of each tree.

Initially, the cages were checked daily for adult emergence. As adults

emerged, they were counted, but not removed. This allowed them to mate and re-oviposit on the mummies from which they emerged. Due to the screened windows of the cages, it was not difficult to count all of the moths present at any time. To determine the number of moths which emerged in a cage on any given day, the number of moths found in the cage on the previous day was subtracted from the number found on the current day. When no new moths had emerged for several consecutive days, all of the moths (most of which were dead) which had accummulated were removed and counted. This number of moths was compared with the cumulative total to be sure that no emerging moths had been missed. Thereafter, until 27 September, the cages were checked every 3 to 5 days for emerging moths. These moths were removed as they were counted. Temperature was recorded continuously in the orchard by a hygrothermograph so that thermal summation calculations could be made.

Degree-day accumulation was calculated using double triangulation with a lower developmental threshold (LDT) of 55°F. In calculating heat unit accumulation, Seaman and Barnes (1982 Annual Report) found that the calculational method which best fit their data on new-crop almonds was using a LDT of 55°F and an upper developmental threshold (UDT) of 94°F with a vertical cutoff. In the present experiment, we desired to examine the need for a 94° UDT with a vertical cutoff in calculating thermal summation on mummy nuts, as well as compare the number of degree-days required for development on mummies in 1983 with that of 1982. Therefore, for each peak of adult emergence in 1983, degree-day accumulation was calculated in 3 different ways: with no UDT; with a 94° UDT and a horizontal cutoff; and with a 94°F UDT and a vertical cutoff.

Regarding upper developmental thresholds, there are 2 major ways of incorporating an upper developmental threshold into a degree-day model.

The first is the use of a horizontal cutoff. This type of cutoff assumes that the developmental rate of an organism increases with increasing temperature until the upper developmental threshold temperature is reached. If the daily temperature increases above the upper threshold temperature, the organism maintains a developmental rate equal to the rate at the upper threshold temperature. In contrast, the second type of cutoff is the vertical cutoff. Here, if the daily temperature goes above the upper threshold temperature, the organism ceases to develop until the temperature again drops below the upper developmental threshold temperature.

Results and Discussion

Figure 1 illustrates the pattern of adult emergence through time from 7/2/83 until 9/27/83 in the field. Table 1 presents the average degree-day accumulation for development from egg to adult on mummy nuts as determined by Seaman and Barnes in 1982, as well as the degree-day accumulation from 5/18/83 (when the mummies were inoculated with first instar larvae) to peak emergence on 7/9/83 (adding 100 degree-days for egg development), and from peak adult emergence on 7/9/83 to the subsequent peak on 9/1/83. (Since 2 separate peaks occurred on 7/7 and 7/12 during the first emergence period (Figure 1), an intermediate date of 7/9 was selected to represent the "peak" of the first emergence).

The accumulated degree-days for development during both Spring and Summer, 1983 (1112 and 1140 degree-days, respectively) correspond very closely to the Spring, 1982 data of Seaman and Barnes (1122 degree-days), as long as the calculations are done using a 94° UDT with a vertical cutoff.

Using the 1983 data, the importance of using a 94° UDT with a vertical cutoff can be seen (Table 1). For the Spring, 1983 data, the accumulated

degree-day values calculated using no UDT (1160 degree-days) and using a 94°F UDT with a horizontal cutoff (1156 degree-days) are only a little higher than those values calculated using a 94°F UDT with a vertical cutoff for both 1982 and Spring, 1983. However, the maximum daily orchard temperature was above 94°F on only 13 days between 5/18/83 and 7/9/83. Therefore, the type of UDT used in the degree-day calculations was only important on 13 days during this period. During the period between 7/9/83 and 9/1/83, however, the maximum daily orchard temperature was above 94°F on 22 days. Therefore, the type of UDT used was more important during this period, as is seen in the data for Summer, 1983 in Table 1. While the accumulated degree-days calculated using a 94°F UDT with a vertical cutoff remained comparable to the Spring data of both 1982 and 1983, the values calculated with either no UDT, or a 94°F UDT with a horizontal cutoff, were much higher. Moreover, in order for a degree-day model to be used for predictions, it must produce consistent results despite variations in temperatures from year to year. Only the degree-day values calculated using a 94°F UDT with a vertical cutoff produced relatively consistent results for both Spring and Summer, 1983.

In summary, the results of the present experiment confirm the use of a 94°F upper developmental threshold with a vertical cutoff in the calculation of degree-day accumulation on mummy almonds in the field. In addition, approximately 1125 degree-days are required for development from egg to adult on mummy nuts in the field, which is more than that required for development on new-crop nuts.

Table 1. Degree-day accumulation for navel orangeworm development (egg to adult) on mummy almonds, using 3 different calculational methods.

Year	No. Moths Emerged	Accumulated Degree-Days			
		No UDT[a]	94°F UDT Horiz. Cutoff	94°F UDT Vertical Cutoff	Range[b]
1982 (Spring)[c]	217	--	--	1122	621-1626
1983 (Spring)[d]	614	1160	1156	1112	876-1400
1983 (Summer)[e]	635	1334	1316	1140	--[f]

a UDT = Upper Developmental Threshold.

b Range values calculated using a 94°F UDT with a vertical cutoff.

c Data from Seaman and Barnes, 1982 Annual Report.

d Maximum daily orchard temperatures was above 94°F on 13 days between inoculation date of 5/18/83 and peak emergence on 7/9/83.

e Maximum daily orchard temperature was above 94°F on 22 days between emergence peak on 7/9/83 and subsequent peak on 9/1/83.

f Cannot be accurately estimated.

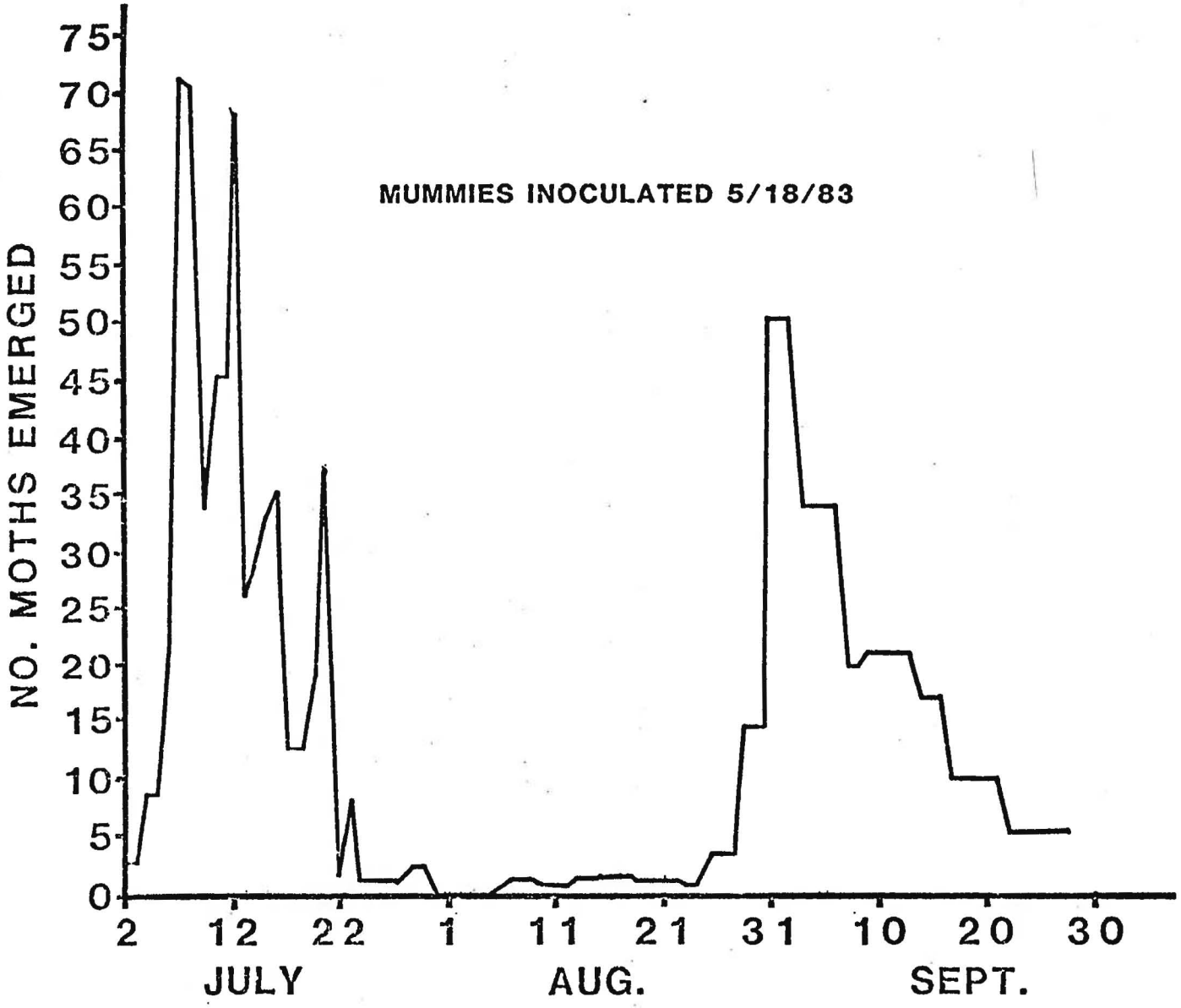

Fig. 1. Number of navel orangeworm moths which emerged each day from caged mummy almonds in the field. The mummies were initially inoculated with 1st-instar larvae on 5/18/83.

INTRA-INSTAR THERMAL SUMMATION FOR NAVEL ORANGEWORM ON NEW-CROP ALMONDS

J. P. Sanderson and M. M. Barnes

This series of experiments was conducted primarily to fill a gap of information which exists in the Navel Orangeworm Simulation Model developed by Drs. Oddson and Aggarwal of the Math Department at U.C. Riverside. The average numbers of degree-days accumulated during the egg and pupal stages have been established, but no work has been done on the degree-days accumulated during each larval instar. This study was conducted in order to determine the number of degree-days accumulated during each instar.

Methods and Materials

Laboratory Study

A laboratory study was conducted to determine the fraction of the total developmental time (from first instar to adult) spent in each instar. The number of degree-days required for development can change, depending on the rearing diet. Therefore, laboratory data on the actual number of degree-days accumulated in an instar reared on a single diet are not as useful as the relative amount of time spent in each instar. This assumes that the relative amount of time spent in each instar would not change with different diets.

One-hundred newly-hatched first instar larvae, which were produced by

field-collected moths, were placed individually in plastic, 35 x 10 mm petri dishes, and provisioned with small chunks of an artificial diet developed for the Beet Armyworm. This diet was used so that the larvae would not become inaccessible, as they would if they tunneled into a nut. The petri dishes were placed into a constant temperature cabinet set at 75°F, 75-85 % RH, and 14:10 photophase/scotophase. The larvae were checked every 8 hours for the presence of a molted head capsule. When a head capsule was found, it was discarded and the event was recorded. Additional chunks of diet were added frequently, when the old chunks were consumed or dehydrated. The development of the larvae was followed to the adult stage. Only those individuals which developed to the adult stage were included in any calculations. To calculate the fraction of the total developmental time spent in each instar, the number of hours spent in each instar was divided by the total number of hours required for development to the adult stage for each individual.

Field Study on New-Crop Almonds

Using a value of 666 degree-days for navel orangeworm development from first instar to adult on new-crop nuts in the field (based on the work of Seaman and Barnes, 1982 Almond Board Annual Report), and the results of the previous laboratory experiment, the predicted average number of degree-days which should accumulate during each instar on new-crop nuts was calculated.

In order to confirm the results of the laboratory experiment, a field study of navel orangeworm development on new-crop nuts was conducted. A 10 year-old, unsprayed almond orchard located ca. 4 mi. north of Shafter, Kern County, was selected as the study site. Prior to hullsplit, 20 individual Nonpareil nuts, still attached to each of 20 trees, were caged to prevent

oviposition by wild moths at the onset of hullsplit. Five cages were slid over nuts in each of the 4 compass quadrants of each tree, including nuts from both the inside and outside of the trees, from 3 to 7 ft. high.

The cages consisted of bottomless, 8 oz. plastic cups with Nylon netting covering the large end and fastened by a rubber band. A sleeve of netting was stapled around the smaller end of the cup and overlapped around the branch with a wire tie.

At hullsplit, new-hatched first instar larvae from the seventh generation of a laboratory colony of navel orangeworm were used to inoculate the caged nuts. A laboratory colony was used as a source of larvae because it would have been too difficult to obtain the quantity of eggs needed for this study from wild moths. Holes were punched into the nutmeats of each nut, and 2 larvae were placed into each of the 400 nuts. Inoculations took place from 7/19/83 to 7/28/83. The date that each nut was inoculated was recorded.

Daily maximum and minumum orchard temperatures needed for degree-day calculations were recorded by means of a hygrothermograph housed in a weather shelter.

A computer program available on the University of California Integrated Pest Management computer system was used to calculate degree-day values. These values were calculated using double triangulation, with a lower developmental threshold of 55°F and an upper developmental threshold of 94°F with a vertical cutoff. Since both the inoculation and sampling procedures were done in the afternoon, the accumulated degree-days were calculated from maximum to maximum temperatures. Each evening, the minimum and maximum temperature for that day was recorded. On the next morning, these values, plus estimates as to the minimum and maximum temperatures for the current day, were entered into the computer via the terminal at the Kern County Farm

Advisor's Office. The computer calculated the actual accumulated degree-day value for the previous day, plus the projected value for the present day. The total accumulated degree-days from each inoculation date to the present could then be calculated.

To verify the laboratory study, nut samples were taken when it was predicted that 50% of the larvae of a particular instar would have molted to the subsequent instar. Therefore, the predicted number of degree-days which should have accumulated from egg hatch through the completion of each of the 6 instars was determined. Each morning, these predicted values were compared with the total accumulated degree-days from each inoculation date to the present. If the predicted values were close to one of the actual values, a decision to sample could be made. For each instar, at least 2 separate samples were taken.

These nut samples were then taken to the laboratory and cracked-out. The larvae or pupae found were placed in ethyl alcohol and labeled as to date inoculated, date sampled, position in tree, and tree number. The width of the head capsule of each larva was measured with a dissecting microscope fitted with a calibrated ocular micrometer. Increased magnification was used to measure the smaller larvae. Using the head capsule measurements, the larvae were classified into one of the 6 instars, based on a head capsule distribution study done by Caltagirone et al. (Environ. Ent. 12(1): 219-221, 1983).

The results of this field study were represented graphically in the following way. By assigning a number to each instar (i.e. first instar = 1, second instar = 2, ..., pupa = 7) and counting the number of individuals of each instar that were found in each sample, an "average instar" number was calculated for each sample. This average instar number of a sample was then plotted against the accumulated degree-days for that sample. In the same

way, the predicted number of degree-days required for 50% of the individuals in a particular instar to molt to the subsequent instar was plotted against an average instar number (e.g. the average instar number for a 50% molt between the third and fourth instars would be 3.5). A line connecting the predicted points was then drawn. It can then be visually observed how close the observed points fall around the predicted line.

Thermal Summation for Total Development on New-Crop Almonds

In 1981 and 1982, Seaman and Barnes developed a thermal summation model for navel orangeworm development on new-crop almonds. To add a third year of data toward validation of their model, 100 of the inoculated nuts mentioned previously were not sampled, so that the larvae inside could develop to the adult stage. The cages were checked daily for adult emergence. Accumulated degree-days were calculated from the inoculation date to the date of emergence for each individual.

Results and Discussion

Laboratory Study

The percent of the total developmental time (from first instar to adult) spent in each instar and the pupal stage, at 75°F, is shown in Table 1. These data are based on 45 individuals which developed to the adult stage. Due to an error, the molt between instars 5 and 6 was missed in many individuals, so the developmental times for these instars were combined. In general, roughly 10 percent of the total developmental time was spent in each of the larval instars.

Regarding the duration of the pupal stage, work by both Engle and Barnes (1980 Almond Board Annual Report) and Sanderson and Barnes (1983 Almond Board Annual Report) calculated a thermal summation of approximately 200 degree-days

for pupal development in the laboratory. Seaman and Barnes (1982 Almond Board Annual Report) calculated 666 degree-days for development from first instar to adult on new-crop almonds in the field. Using the results in Table 1 for the pupal stage, 30.7 percent of 666 degree-days equals 204.5 degree-days for pupal development, which closely agrees with the previous work.

Field Study on New-Crop Almonds

As mentioned in the results of the laboratory study, the developmental times spent in the fifth and sixth instars were combined. For the purposes of the field study, this combined value was divided in half, therefore assuming that 16.4% of the developmental time from first instar to adult is spent in each of the fifth and sixth instars.

Figure 1 is a plot of the average instar number vs. accumulated degree-days for 17 samples, compared to a line representing the predicted values. Visually, the observed points fall very close to the predicted line at each instar, indicating good agreement between the predicted values based on the laboratory data and the observed values from new-crop nuts in the field. Therefore, it appears that the results of the laboratory study probably can be used to approximate the thermal summation of each instar of individuals developing on new-crop almonds. However, the study should be repeated for verification. This study should also be done on mummy almonds.

Thermal Summation for Total Development on New-Crop Almonds

A total of 105 moths emerged from the 100 inoculated nuts which were reserved for adult emergence. The average thermal summation for development from first-instar larvae to adult was 777 degree-days, using a 55°F lower threshold and a 94°F upper threshold with a vertical cutoff. The addition

of 100 degree-days for egg development would indicate a thermal summation for total development of 877 degree-days. A histogram of adult emergence vs. accumulated degree-days is illustrated in Figure 2.

Table 2 compares the results of the present experiment with that of Seaman and Barnes for 1981 and 1982. It is apparent that the 1983 value for average total development of 877 degree-days is ca. 100 degree-days more than the values from both 1981 and 1982. Most probably this discrepancy is due to the fact that Seaman and Barnes used wild navel orangeworm in their studies, whereas the individuals in the present study were members of the seventh generation of a laboratory colony maintained at 75°F. Table 2 also demonstrates the advantage of using a 94°F upper threshold with a vertical cutoff for predictive purposes.

Table 1. Percent of total developmental time (from first instar to adult) spent in each instar and pupa of navel orangeworms reared on an artificial diet at 75°F, 75-85% RH, and 14:10 photophase.

Instar	Avg. % Duration[a]	S.D.	Range
1	9.5	1.26	6.7-12.8
2	7.8	1.12	5.4-10.8
3	8.6	1.40	6.0-12.2
4	10.7	1.45	8.4-14.0
5-6	32.7	6.76	20.0-48.6
Pupa	30.7	3.74	21.3-42.6

a Based on 45 individuals

Table 2. Average degree-days accumulated for navel orangeworm development (egg to adult)[a] on new-crop almonds for 3 years, using different methods of degree-day calculations.

Year	No. Moths Emerged	Accumulated Degree Days			
		No UDT[b]	94°F UDT Horiz. Cutoff	94°F UDT Vert. Cutoff	Range[c]
1981[d]	207	1025	--	763	580-1006
1982[d]	236	874	--	769	594-1126
1983	105	1003	994	877	694-1122

a Includes 100 degree-days for egg development.

b. UDT = Upper Developmental Threshold.

c Calculated using 94°F UDT with a vertical cutoff.

d Data from Seaman and Barnes, 1982 Almond Board Annual Report.

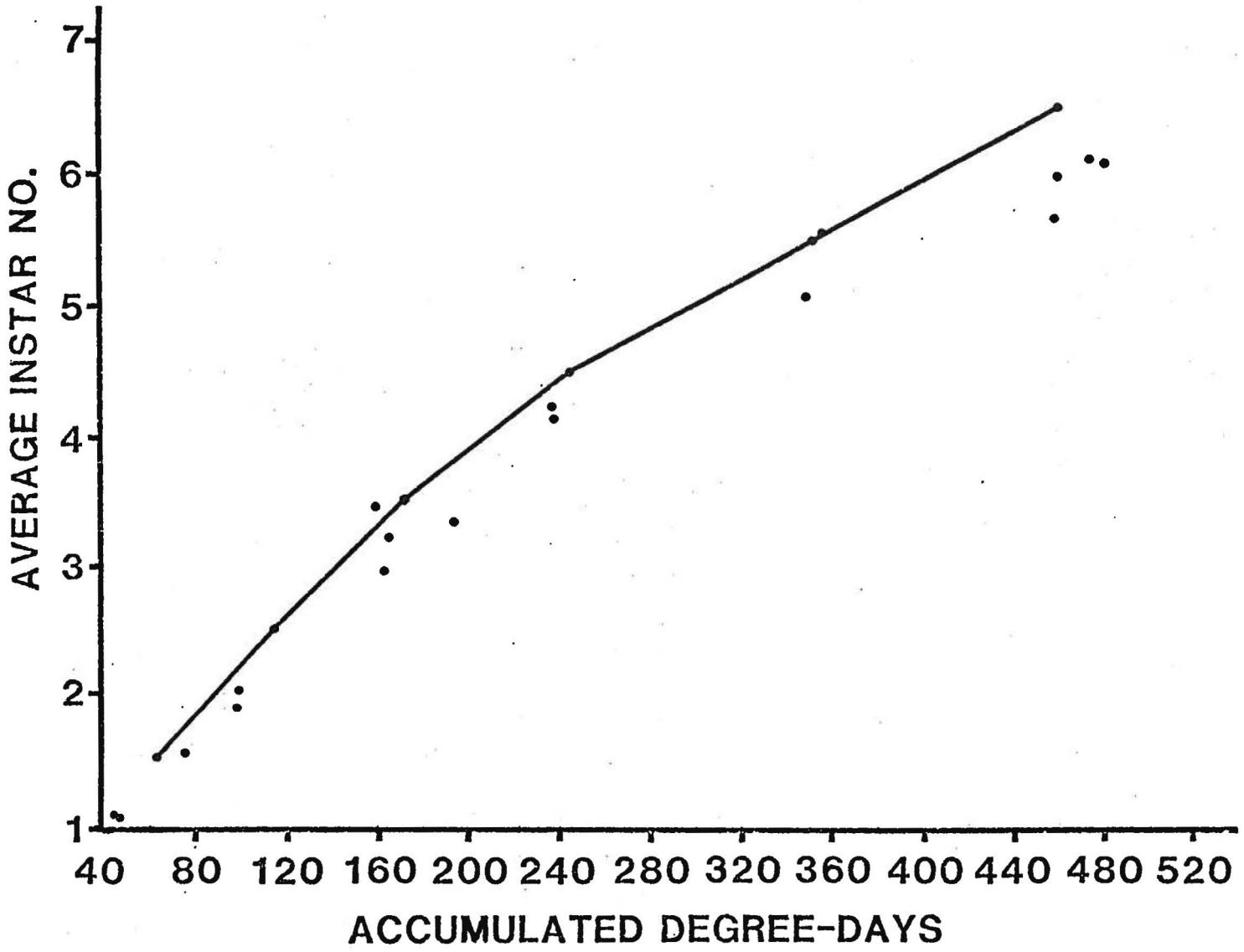

Fig. 1. "Average instar" number (see text) of the individuals recovered in each of 17 almond samples vs. the thermal summation from the inoculation date until each sample date. Solid line represents predicted values.

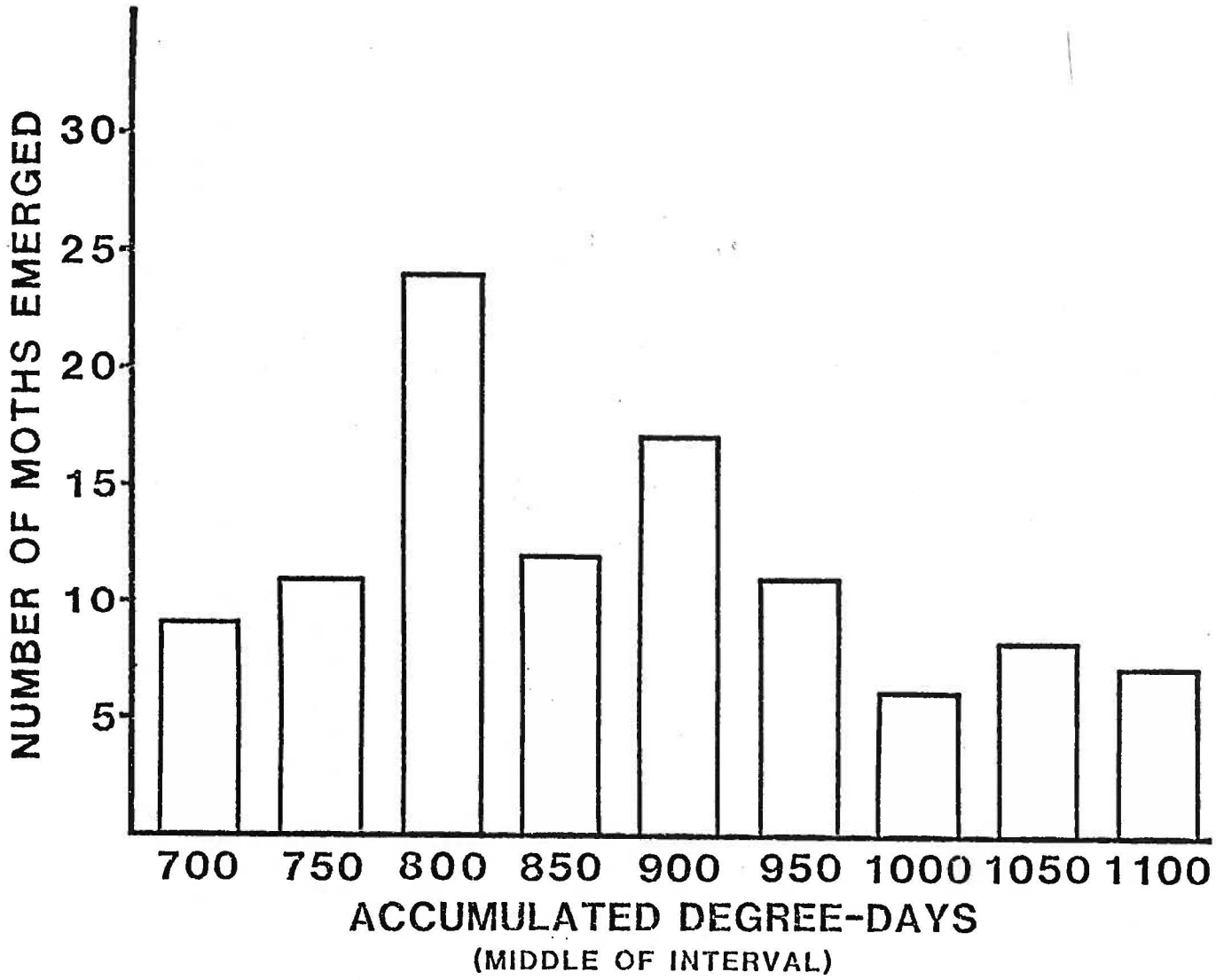

Fig. 2. Histogram of moth emergence from caged Nonpareil almonds vs. accumulated degree-days, Kern Co., CA, 1983.

AN ATTEMPT TO VERIFY THERMAL SUMMATION FOR NAVEL ORANGEWORM DEVELOPMENT USING BLACKLIGHT TRAP CATCHES

J. P. Sanderson and M. M. Barnes

In the 1982 Annual Report, Seaman and Barnes used blacklight traps to monitor navel orangeworm populations in order to provide evidence for the validity of a thermal summation model which they developed for navel orangeworm development on new-crop almonds. They argued that since the navel orangeworm cannot infest the new-crop nuts until hullsplit, the initiation of hullsplit would be a logical biofix where thermal summation calculations should begin in order to predict the development of the population. If hullsplit initiation is to be used as a biofix, then the number of degree-days between hullsplit initiation and peak blacklight trap catch should be roughly equal to the observed number of degree-days required for total development on new-crop nuts in the field. The results of their studies with blacklight traps in both 1981 and 1982 were in excellent agreement with their predictions.

The present study with blacklight traps was conducted to further validate the thermal summation model developed by Seaman and Barnes on new-crop nuts.

Methods and Materials

This study was conducted in unsprayed sections of 3 almond orchards.

One orchard was located ca. 4 mi. north of Shafter in Kern County, and consisted of 10 year-old flood irrigated trees. The other 2 were located ca. 6 mi. northeast of Delano in Tulare County, and contained 14 year-old, flood irrigated trees.

To detect hullsplit initiation at eye-level, 20 trees were selected at random within a 10-acre plot in each of the orchards. For each tree, 9 nuts from each of the 4 compass quadrants were checked for a hullsplit condition. A nut was considered hullsplit when the hull was visibly separated along its suture. Surveys were conducted every 4 days until hullsplit initiation was detected.

After hullsplit initiation was detected, one blacklight trap was positioned in the center of each of the three 10 acre plots. The traps were operated nightly by means of a photocell which turned them on and off. Flying insects were attracted to the trap's 8-watt bulb, hit the vanes which surrounded it, and fell through a funnel into a plastic bag which contained a vapona insecticide strip. The plastic bags were collected and replaced daily. Navel orangeworm moths were sorted from all the other insects in each bag and counted.

Orchard temperatures were recorded continuously with a hygrothermograph housed in a weather shelter in each of the 10-acre plots. Thermal summation calculations were done using double-triangulation with a 55°F lower developmental threshold and a 94°F upper developmental threshold with a vertical cutoff. For each of the 3 orchards, the accumulated degree-days between the initiation of hullsplit and peak moth catch was calculated.

Results and Discussion

Figures 1-3 illustrate the total nightly catch of navel orangeworm moths

through time for each of the 3 orchards. Table 1 presents the accumulated degree-days between the initiation of hullsplit and peak moth catch for 1981, 1982, and 1983.

Hullsplit initiation, as observed at eye-level, commenced on 7/11/83 in 2 of the orchards, and on 7/10/83 in the third. Peak blacklight catches occurred on 9/5 - 9/6, which was much later than the peaks reported by Seaman and Barnes (1982 Annual Report). The results in Table 1 indicate that, in all 3 orchards, many more degree-days were accumulated between hullsplit initiation and peak blacklight trap catch in 1983 than in 1981 and 1982.

These results do not invalidate the thermal summation model of Seaman and Barnes, however. It is possible that, for some reason, the bulk of the navel orangeworm population did not enter the new-crop nuts until sometime after the initiation of hullsplit. If this is true, then some moth activity should be detectable approximately 766 degree-days prior to the peak blacklight trap catch, since Seaman and Barnes demonstrated that an average of 766 degree-days are required for development on new-crop almonds. Seven-hundred-sixty-six degree-days prior to the peak blacklight trap catches corresponds to sometime between July 29 - Aug. 1 for all 3 orchards. Figures 1-3 indicate a slight amount of moth activity around this time. Although the moth levels appear to be insignificant, perhaps the navel orangeworm population was very low at this time due to the scarcity of mummies in these orchards, so that it would be difficult to accurately assess the population with blacklight trap catches.

It should also be noted from Figures 1-3 that a small but substantial peak occurred on 8/17/83 in all 3 orchards. Averaging the accumulated degree-days from hullsplit initiation to this peak for the 3 orchards produces an average of 777 degree-days, which agrees very well with the data of Seaman and Barnes.

Lastly, note that the peak blacklight trap catch did not occur prior to the accumulation of 766 degree-days after the initiation of hullsplit. If the peak had occurred much before the accumulation of 766 degree-days, then it would appear that the model was in error. However, this was not the case.

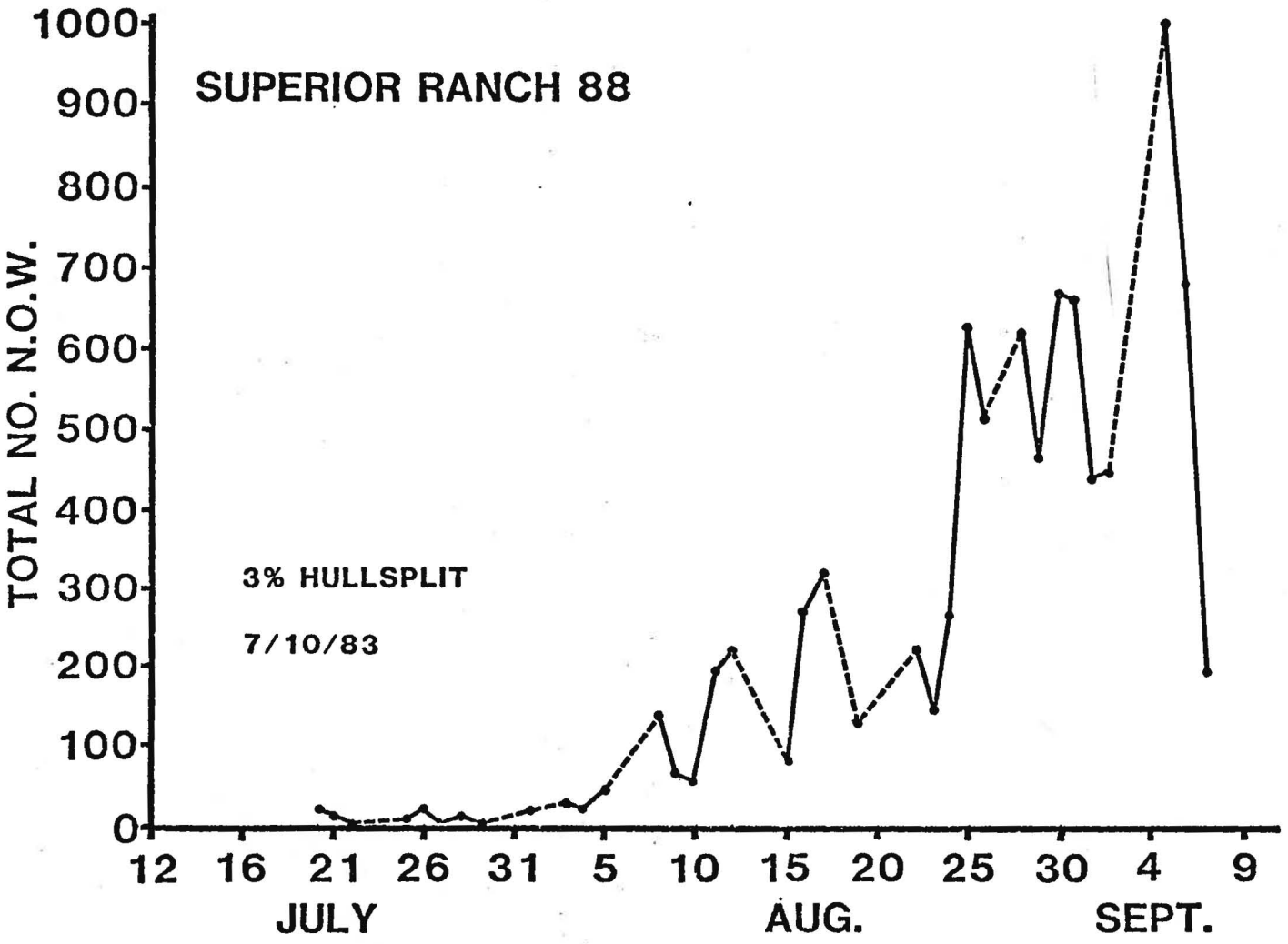

Fig. 1. Blacklight trap catch of navel orangeworm moths on almonds, Kern Co., CA, 1983. Dashed lines represent periods when no data were collected.

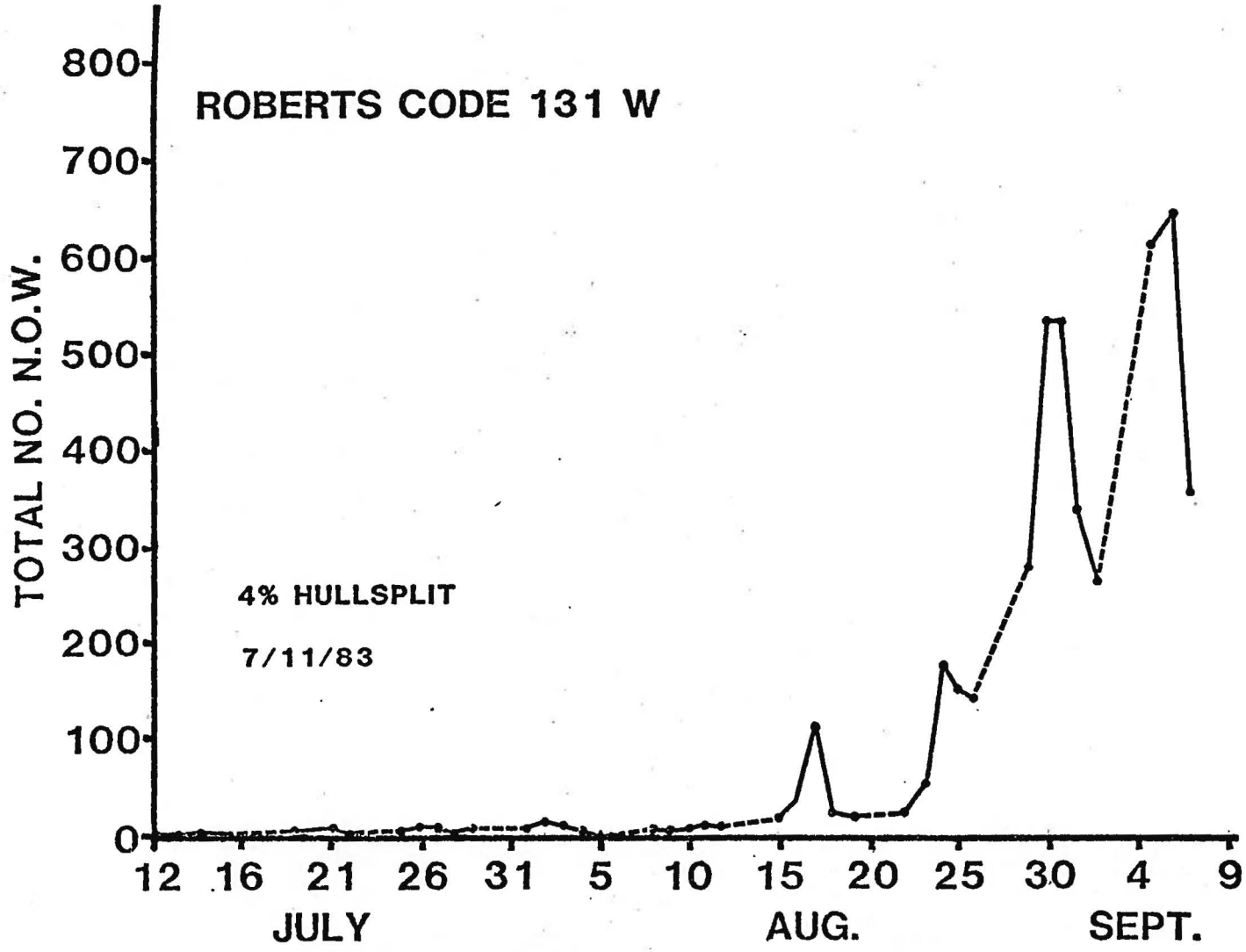

Fig. 2. Blacklight trap catch of navel orangeworm moths on almonds in orchard no. 1, Tulare Co., CA, 1983. Dashed lines represent periods when no data were collected.

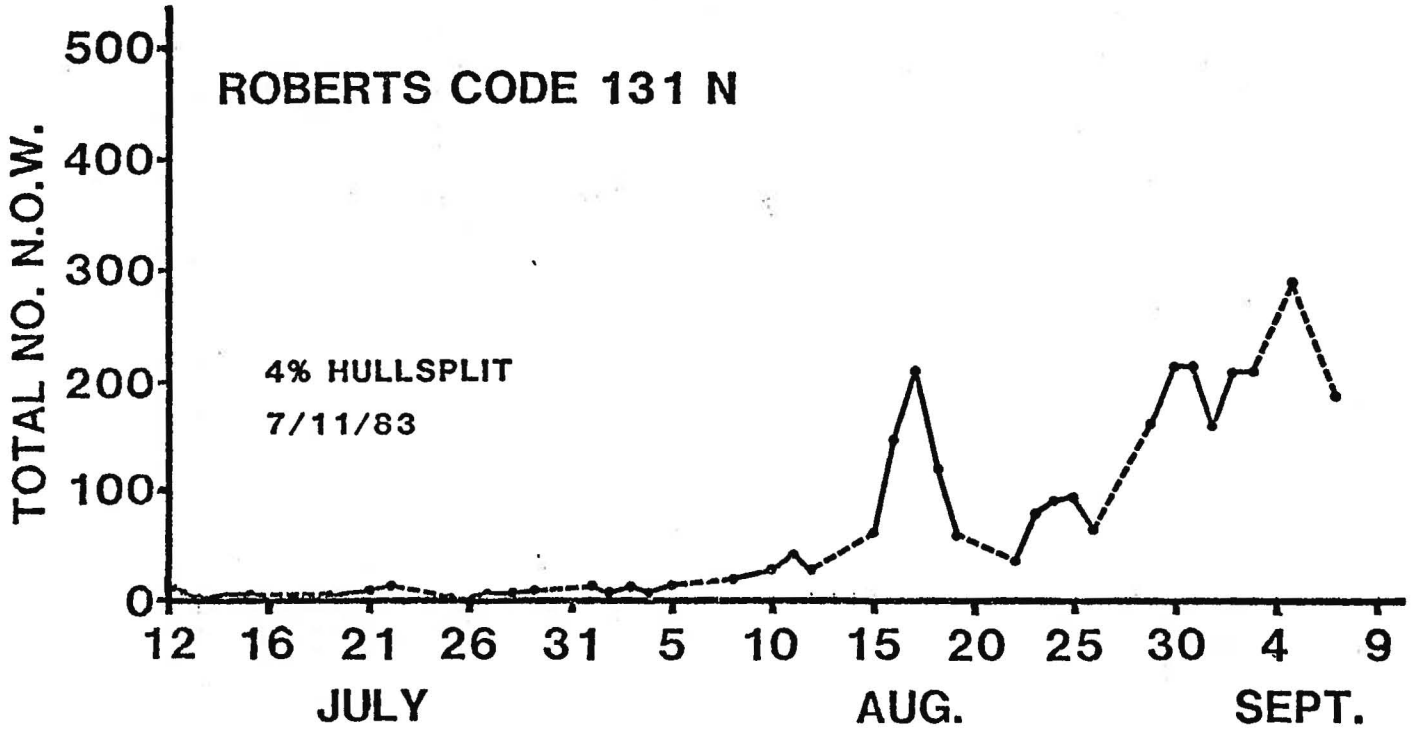

Fig. 3. Blacklight trap catch of navel orangeworm moths on almonds in orchard no. 2, Tulare Co., CA, 1983. Dashed lines represent periods when no data were collected.

Table 1. Accumulated degree-days from hullsplit initiation (measured at eye-level) to peak blacklight catch for 3 years.

Year	Orchard	% Hullsplit	Peak Moth Catch	Accumulated Degree-Days[a]
1981	--	5	8/12	778
1982	--	2-3	8/18	785
1983	Ranch 88	3	9/5	1208
1983	Code 131W	4	9/6	1167
1983	Code 131N	4	9/5	1095

a Calculated using a 94°F upper developmental threshold with a vertical cutoff.

ABILITY OF THE NAVEL ORANGEWORM TO DEVELOP AND REPRODUCE ON CAGED MUMMY NUTS IN THE FIELD

J. P. Sanderson and M. M. Barnes

Winter sanitation of mummies is an excellent cultural control measure against the navel orangeworm. Releases of exotic parasites such as Goniozus legneri may be an additional aid in reducing navel orangeworm levels. However, the removal and destruction of mummy almonds which are infested with navel orangeworm larvae reduces the availability of hosts for insect parasites. With few or no navel orangeworm hosts available during the winter and spring, any parasites which may be present would not be able to build up in sufficient numbers to provide a significant degree of in-season control. Therefore, it was decided to place infested mummy nuts in cages and determine the ability of the navel orangeworm to not only develop and reproduce on these caged mummies, but also to increase their numbers. These cages containing navel orangeworm could then provide hosts for the parasites to exploit in order to build up their numbers.

Methods and Materials

Data for the present study were collected during the execution of the experiment to determine the thermal summation for navel orangeworm development on mummy almonds in the field. Therefore, the methods and materials

used are the same for both of these reports.

Results and Discussion

Figure 1 in the report entitled, "Thermal Summation for Navel Orangeworm Development on Mummy Almonds in the Field" graphically represents the pattern of adult emergence through time in the mummy cages. A total of 614 of the first-instar larvae which were initially used for inoculation developed to the adult stage on the caged mummy almonds. They mated and laid a large number of eggs back on the mummies from which they emerged, although some eggs were also laid on the walls of the cages. By this time, the mummies were very dry, and a high degree of mortality must have occurred in the second generation of larvae due to a lack of moisture. Also, several arthropod predator species were common within the cages, such as green lacewing larvae, crab spiders, and minute pirate bugs. These predators undoubtedly added to the total mortality. As a result, only 635 moths of the second generation completed development on the mummies in the cages.

The navel orangeworm was therefore able to recycle on the caged mummies. However, under the conditions of this experiment, they did not substantially increase in number, although they did not decrease either.

Perhaps the caged mummies would not be so dry in early spring so that the mortality of the larvae produced by the emerging overwintering population would be lower. Then, the navel orangeworm population might increase within the cages, providing more hosts for the parasites.

A WITHIN-TREE DISTRIBUTION STUDY OF PEACH TWIG BORER INFESTATION IN NONPAREIL ALMONDS

R. R. Youngman and M. M. Barnes

Current sampling techniques used to estimate nut infestation by peach twig borer and other arthropod pests, involves removing a portion of nuts from the tree's total crop which has been shaken from the tree. While this method provides random nut samples taken from virtually anywhere on the tree, it can be very labor intensive; especially if the trees are harvested by hand. Information about the pattern of infestation by peach twig borer was studied to seek improvements in this sampling method.

Materials and Methods

The orchard used in this study consisted of ten year old trees and is located about four miles north of Shafter in Kern County. The study plot was located near the center of a 304 acre block which has not received any 'in season' pesticide treatments since 1980. It did receive however, a dormant application of Supracide 2E at a rate of 1 gal a.i. per acre during the week of December 10-15, 1982.

A block consisted of four adjacent trees, and from each tree there was selected one quadrant facing either the north, south, east or west side. Blocks were replicated eight times and separated at least four rows from one

another along a north-south line in the orchard. Within a quadrant, two samples of two hundred nuts each were removed from both the upper and lower halves of the tree's canopy. The lower sample was obtained first, by knocking nuts onto a tarp from branches in the lower half of the canopy. The tarp was then cleared of nuts and replaced, and the upper sample was obtained by knocking nuts from branches in that half of the canopy. The samples were taken back to the lab at UCR and placed in cold storage until they could be cracked out to determine percent infestation.

Results and Discussion

The mean infestation was 2.7% in nuts from the upper canopy half, and was significantly greater ($P<0.01$) than the 0.9% from the lower canopy half. The effect of directions on infestation however, were not significantly different (Table 1).

Based on these results, it appears that within-tree nut infestation by peach twig borer is not random when considering vertical infestation. There are two possible explanations for this: the first is that a female moth flies randomly into the canopy and then for some reason prefers to oviposit on nuts in the upper half of the tree. The other possibility is based on the assumption that female moths fly predominately above the canopy, and when ovipositing come in contact more often with nuts in the upper half. In addition, it is known that hullsplit occurs earliest in nuts located at the top of the tree which may also be a factor responsible for this difference in infestation between vertical levels. The latter possibility is indirectly supported (as far as male peach twig borer mating activity is concerned), by a study done by Rice and Jones, J. Econ. Entomol. 68: 358-360 (1975). Part of their study dealt with the relationship of peach twig borer

male moth counts to pheromone trap placement. While they did not obtain significant differences between trap height levels, they noticed that on calm wind nights more male moths were captured in traps placed at higher levels. Conversely, on windy nights they found that more males were caught in traps at the lower levels.

At present, no changes are recommended for the current sampling method without further research.

Table 1. Relationship of peach twig borer infestation in "Nonpareil" almonds to compass direction, Kern Co., 1983.

Direction	Percent Infestation
North	2.1 a[1/]
West	2.0 a
East	1.8 a
South	1.3 a

1 Means are averages of eight single-tree replicates. Means followed by the same letter are not significantly different at P=0.05 using Duncan's NMRT.

EFFECTS OF PEACH TWIG BORER PHEROMONE TRAP DENSITY ON TRAP CATCHES

R. R. Youngman and M. M. Barnes

The effects of competition for moths among traps too closely spaced, can result in subnormal catches. Therefore, the main objective of this study was to maximize trapping efficiency by determining the optimum density for peach twig borer pheromone traps. Once this optimum density is found, it can be used as a standard for future sampling studies as well as for routine monitoring of the seasonal population trends of this pest.

Materials and Methods

The orchard used in this study consisted of ten year old trees planted on a 24 x 24' row-tree spacing plan. It was located about four miles north of Shafter in Kern County. The study plot was located in the northeast half of a 304 acre block which has not received any 'in season' pesticide treatments since 1980. It did receive, however, a dormant application of Supracide 2E at a rate of 1 gal a.i. per acre during the week of December 10-15, 1982.

The main plot consisted of four subplots, and within each subplot 16 Pherocon® 1C pheromone traps were set out in a 4 x 4 grid; each at a height of 5 to 6 feet in the northeast quadrant of the tree. The four subplots were separated from each other by 1248 feet to the north and south, and by

1010 feet to the east and west.

The 16 traps were spaced at one of the following densities: one trap per every tree and every row, one per every 2nd tree and 2nd row, one per every 4th tree and 4th row, and one per every 8th tree and 8th row. The ratio of traps to trees was: 1/1, 1/4, 1/16, and 1/64 respectively. The lowest trap-density treatment of one trap per every 18th tree and 18th row required too large of an area to allow it to be included in the main plot. It consisted of 3 traps spaced 18 trees apart in a line, and was located 900 feet to the west of the main plot in the same orchard. The four treatment locations within the main plot were re-randomized each week.

The traps were set out on June 22, 1983 and all peach twig borer moths from the inner four pheromone traps (within the sixteen) were counted and removed on a weekly basis. The moths in the twelve border traps were removed biweekly, but not recorded. The reason why only those moths in the inner four traps were recorded and not the rest, is based on the assumption that only the inner four traps within a 4 x 4 grid are under equivalent trap competition conditions.

The peach twig borer pheromone caps were replaced every two weeks in all 67 traps, and the sticky liners were changed every 2 to 4 weeks depending on moth flight activity.

Results and Discussion

The peach twig borer moth population did not remain static from week to week. Therefore, to be able to analyze the data, the mean moth catch per treatment was divided by the mean moth catch in the highest trap density for each week.

A two-way analysis of variance was performed on the raw data, and the

treatment means proved to be significantly different ($P<0.05$). As noted in Table 1, the two highest trap-area treatments (lowest ratio of traps to trees) of 4.28 and 0.85 acres per trap, caught signigicantly more moths than the two lowest trap-area treatments of 0.05 and 0.01 acres per trap. This relationship is illustrated in Fig. 1; as the trap area increases to 0.85, the trap catch factor also increases and reaches a peak at 1.96.

When more than one pheromone trap is used in an almond orchard to monitor the peach twig borer population, the optimum density should be no less than one trap per acre.

Table 1. Effects of pheromone trap density on male peach twig borer moth catch.

Ratio of Traps to Trees	Trap Area (No. Acres per Trap)	Trap Catch Factor
1/64	0.85	1.96 a[1/]
1/324	4.28	1.69 a
1/16	0.21	1.45 ab
1/4	0.05	1.06 b
1/1	0.01	1.00 b

1 Means are averages of 11 weekly replicates (4 traps per treatment). Means followed by the same letter are not significant at P=0.05 using Duncan's NMRT.

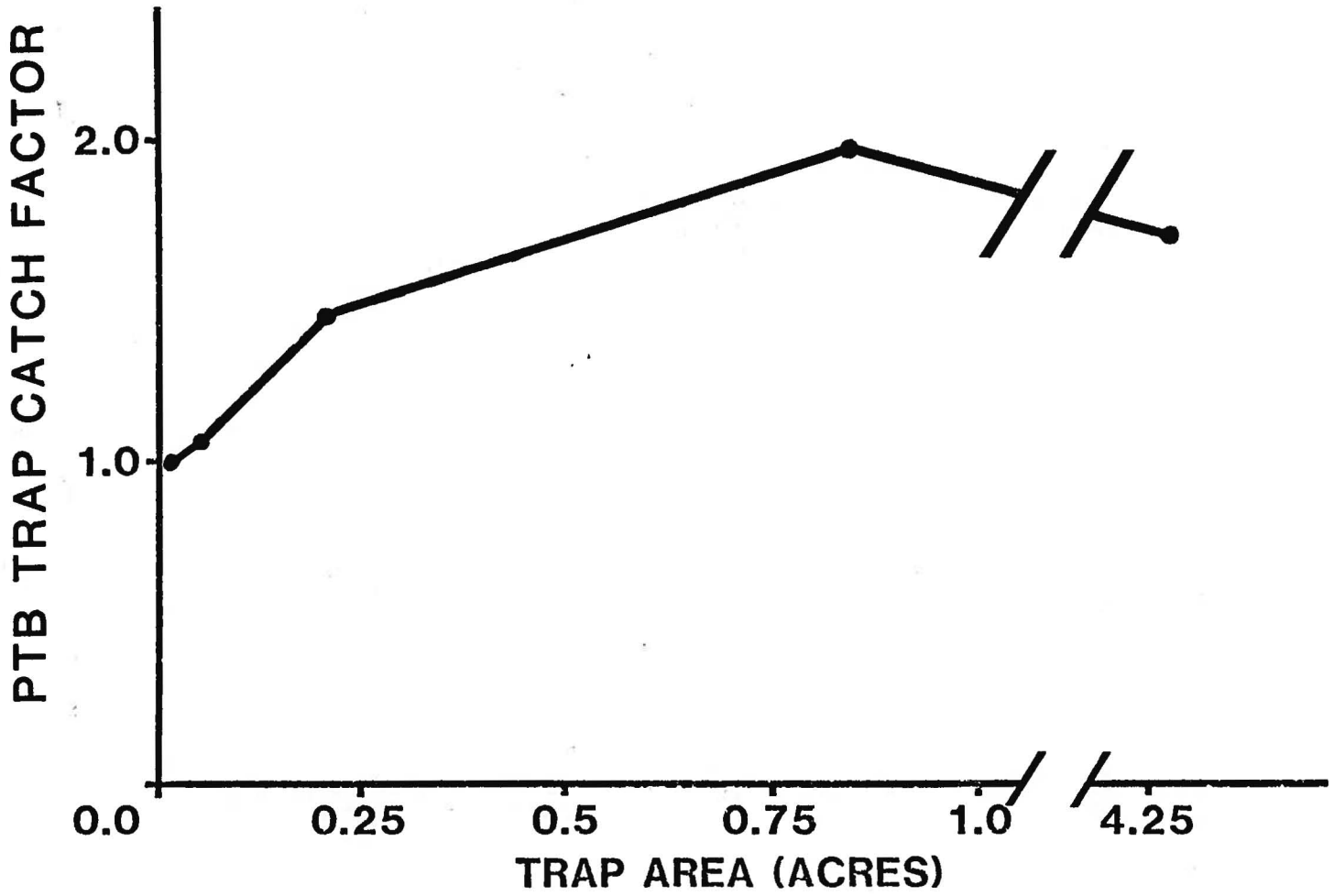

Fig. 1. Relative increase in moth catch as a function of trap area.

FIELD ACARICIDE TRIALS

R. R. Youngman, M. M. Barnes and E. F. Laird

A field experiment evaluating the effects of thirteen compounds and a water check on the population levels of both spider mites and predatory arthropods, was conducted in the southern San Joaquin Valley from July 27 through September 7, 1983. The compounds MK-936, NC-21314, Mavrik 2EC, Mavrik 2F, FMC-54800, SC-1069 and S-3206 were compared to a currently registered acaricide, Omite 30W and a water check.

Materials and Methods

The orchard used in this trial consisted of 3rd leaf Nonpariel variety almonds which were drip-irrigated. The experimental plot was located 3.2 miles east of Hwy. 99 and 1 mile north of Kimberlina road in Kern Co.

A randomized block design, replicated six times, was used in assigning the treatments.

A high pressure handgun with a #8 disc was used to apply the materials at 400 - 450 psi. The trees were sprayed until run-off resulting in an application rate of approximately 800 gal/acre. The majority of the compounds were applied on July 27, with the rest on July 28.

A total of 20 leaves per tree, 5 from each of the four cardinal point quadrants, were randomly removed from a height of 5 to 8 feet. All samples

were refrigerated until counts could be made with a dissecting microscope.

Thirteen male spider mites from the pre-treatment sample were identified from slide mounts and all were determined to be Tetranychus pacificus, the Pacific spider mite. The predatory complex consisted of mites in the family Phytoseiidae; the sixspotted thrips, Scolothrips sexmaculatus; the coccinellid beetle, Stethorus sp.; and the lacewing, Chrysopa sp.

Results and Discussion

The pre-treatment sample (July 25) consisted of extremely high spider mite and predator densities (Tables 1 and 2). Two important consequences of these high densities may have led to the decline in the host substrate and high predators numbers. The lack of any appreciable post-spray spider mite resurgence may be attributed, in part, to these two factors.

As shown in Table 1, a dramatic decline in the mite population occurred in all treatments including the water check after one week. A similar decline occurred as well in the predator complex shown in Table 2. This overall drop in population levels was apparently due to the physical removal of both spider mites and predators from the washing effect of the spray application. However, with regard to the predator complex on the water check trees this explanation does not account for the increase in numbers. Table 2 shows an increase from 0.58 to 0.78 predators per leaf by week one. Furthermore, Tables 3 and 4 reveal that while the phytoseiid mite numbers remained unchanged, the sixspotted thrips actually increased from 0.28 to 0.40 thrips per leaf. This probably was responsible for the subsequent decline in the spider mite numbers on the check trees by week two.

The compounds S-3206, Mavrik 2EC and Mavrik 2F were the only treatments with significantly greater mite levels, when compared to the Omite standard

at weeks one and two. Additionally, by week two they became statistically separable from the water check who's population dropped by more than 98 percent.

By week three, S-3206, Mavrik 2EC and Mavrik 2F were no longer statistically different from the water check and Omite standard. There did occur however, a slight resurgence in mite numbers on trees sprayed with 0.06 and 0.1 lbs ai per acre of FMC-54800. These two treatments were the only ones found to be significantly greater than the water check and Omite standard.

Throughout the remainder of the sampling period (weeks 4-6), the FMC-54800 treatments continued to be the only ones which contained spider mite densities significantly greater than the Omite standard and water check.

With reference to Table 4, the oil treatment appeared to favor the six-spotted thrips population over all other treatments including the water check. Additionally, trees sprayed with Mavrik 2EC supported a statisically higher sixspotted thrips population after three weeks (Table 5).

This year's trial was not able to statistically detect any material in being better able to control spider mites when compared to the Omite standard.

Differences between treatments in spider mite and predator densities did occur in this trial. However, it is possible that these may have become more evident if the host substrate was in better condition, and if the predator population was less pronounced as noted previously in relation to the pre-treatment sample (Tables 1 and 2).

No phytotoxicity was observed associated with any treatments.

Table 1. Mean number of active stages of Pacific mite per leaf[a], Kern County, California, 1983[b].

	Material	Rate (ai/acre)[c]	Sample Date 7-25 Pretrt.	8-3 1 week	8-10 2 weeks	8-17 3 weeks	8-24 4 weeks	8-31 5 weeks	9-7 6 weeks
1.	415 NR Oil	1 qt/100 gal	90.6 a	4.5 cde	0.1 b	0.4 c	0.0 c	0.0 b	0.0 b
2.	MK-936 0.15EC + 415 NR Oil	0.4 oz 1 qt/100 gal	80.3 a	2.5 de	0.0 b	0.0 c	0.0 c	0.0 b	0.0 b
3.	MK-936 0.15EC + 415 NR Oil Ambush 2E	0.4 oz 1 qt/100 gal 0.2 lb	94.8 a	6.4 bcd	0.1 b	0.04 c	0.0 c	0.0 b	0.0 b
4.	NC-21314 50SC	0.5 lb	78.6 a	2.8 de	0.0 b	0.02 c	0.0 c	0.0 b	0.0 b
5.	NC-21314 50SC + Triton AG98	0.5 lb 59 ml/100 gal	69.7 a	1.4 e	0.02 b	0.0 c	0.0 c	0.0 b	0.0 b
6.	NC-21314 50SC + Plictran 50WP	0.5 lb 1 lb	74.8 a	0.5 e	0.08 b	0.02 c	0.02 c	0.0 b	0.0 b
7.	Mavrik 2EC	0.1 lb	82.4 a	10.1 ab	2.2 a	3.1 bc	0.6 c	0.09 b	0.0 b
8.	Mavrik 2F	0.1 lb	81.1 a	8.7 abc	2.4 a	1.0 c	0.01 c	0.02 b	0.0 b
9.	FMC-54800 2EC	0.06 lb	75.5 a	2.5 de	1.5 ab	11.1 a	3.3 a	1.0 a	0.2 a
10.	FMC-54800 2EC	0.1 lb	80.6 a	2.4 de	0.4 b	5.3 b	2.1 b	0.7 a	0.3 a
11.	SC-1069 4EC	2.0 lb	72.1 a	0.3 e	0.04 b	0.04 c	0.03 c	0.0 b	0.0 b
12.	S-3206 2.4EC	0.2 lb	79.6 a	11.8 a	2.7 a	0.6 c	0.04 c	0.0 b	0.0 b
13.	Omite 30WP	3.0 lb	84.4 a	2.4 de	0.0 b	0.07 c	0.0 c	0.0 b	0.0 b
14.	Water	--	70.0 a	10.5 ab	0.2 b	0.8 c	0.03 c	0.0 b	0.07 b

a Means are based on 6 replicates of 20 leaves/tree.

b Means in the same column followed by the same letter are not significantly different at the P=0.05 level using Duncan's NMRT.

c Applied with high pressure handgun at 800 gal/acre.

Table 2. Mean number of active stages of predatory arthropods per leaf[a], Kern County, CA., 1983[b].

	Material	Rate (ai/acre)[c]	Sample Date 7-25 Pretrt.	8-3 1 week	8-10 2 weeks	8-17 3 weeks	8-24 4 weeks	8-31 5 weeks	9-7 6 weeks
1.	415 NR Oil	1 qt/100 gal	0.67 a	0.67 ab	0.05 a	0.03 c	0.0 a	0.0 a	0.0 a
2.	MK-936 0.15EC + 415 NR Oil	0.4 oz 1 qt/100 gal	0.41 a	0.25 cd	0.01 a	0.02 c	0.0 a	0.0 a	0.01 a
3.	MK-936 0.15EC + 415 NR Oil + Ambush 2E	0.4 oz 1 qt/100 gal 0.2 lb	0.57 a	0.28 cd	0.08 a	0.02 c	0.0 a	0.0 a	0.0 a
4.	NC-21314 50SC	0.5 lb	0.89 a	0.48 bc	0.01 a	0.03 c	0.0 a	0.0 a	0.01 a
5.	NC-21314 50SC + Triton AG98	0.5 lb 59 ml/100 gal	0.70 a	0.35 cd	0.0 a	0.01 c	0.0 a	0.0 a	0.01 a
6.	NC-21314 50SC + Plictran 50WP	0.5 lb 1 lb	0.80 a	0.03 d	0.02 a	0.03 c	0.0 a	0.0 a	0.0 a
7.	Mavrik 2EC	0.1 lb	0.93 a	0.12 d	0.13 a	0.49 a	0.0 a	0.0 a	0.0 a
8.	Mavrik 2F	0.1 lb	0.70 a	0.13 d	0.06 a	0.29 ab	0.0 a	0.0 a	0.0 a
9.	FMC-54800 2EC	0.06 lb	0.60 a	0.08 d	0.08 a	0.13 bc	0.0 a	0.0 a	0.0 a
10.	FMC-54800 2EC	0.1 lb	0.52 a	0.03 d	0.0 a	0.08 bc	0.0 a	0.01 a	0.0 a
11.	SC-1069 4EC	2.0 lb	1.54 a	0.04 d	0.0 a	0.03 c	0.0 a	0.0 a	0.0 a
12.	S-3206 2.4EC	0.2 lb	0.64 a	0.24 cd	0.04 a	0.18 bc	0.01 a	0.0 a	0.0 a
13.	Omite 30WP	3.0 lb	0.83 a	0.13 d	0.03 a	0.0 c	0.0 a	0.0 a	0.0 a
14.	Water	--	0.58 a	0.78 a	0.04 a	0.12 bc	0.0 a	0.01 a	0.03 a

[a] Means are based on 6 replicates of 20 leaves per tree.

[b] Means in the same column followed by the same letter are not significantly different at the P=0.05 level using Duncan's NMRT.

[c] Applied with a high pressure handgun at 800 gal/acre.

Table 3. Mean number of active stages of predatory arthropods per leaf[a], Kern County, CA., 1983[b].

	Material	Rate (ai/100 gal)[c]	Sample Date 7-25-83			
			Phytoseiidae	Scolothrips sexmaculatus	Stethorus sp.	Chrysopa sp.
1.	415 NR Oil	1 qt/100 gal	0.1 a	0.28 a	0.27 a	0.03 a
2.	MK-936 0.15EC + 415 NR Oil	0.4 oz 1 qt/100 gal	0.07 a	0.28 a	0.06 a	0.0 a
3.	MK-936 0.15EC + 415 NR Oil + Ambush 2E	0.4 oz 1 qt/100 gal 0.2 lb	0.17 a	0.28 a	0.13 a	0.0 a
4.	NC-21314 50SC	0.5 lb	0.4 a	0.38 a	0.09 a	0.03 a
5.	NC-21314 50SC + Triton AG98	0.5 lb 59 ml/100 gal	0.13 a	0.34 a	0.19 a	0.03 a
6.	NC-21314 50SC + Plictran 50WP	0.5 lb 1 lb	0.49 a	0.17 a	0.14 a	0.0 a
7.	Mavrik 2EC	0.1 lb	0.48 a	0.28 a	0.17 a	0.0 a
8.	Mavrik 2F	0.1 lb	0.31 a	0.28 a	0.08 a	0.03 a
9.	FMC-54800 2EC	0.06 lb	0.27 a	0.23 a	0.11 a	0.0 a
10.	FMC-54800 2EC	0.1 lb	0.23 a	0.15 a	0.14 a	0.0 a
11.	SC-1069 4EC	2.0 lb	0.89 a	0.48 a	0.18 a	0.0 a
12.	S-3206 2.4EC	0.2 lb	0.11 a	0.26 a	0.28 a	0.0 a
13.	Omite 30WP	3.0 lb	0.35 a	0.24 a	0.23 a	0.0 a
14.	Water	--	0.23 a	0.28 a	0.08 a	0.0 a
Column Means			0.30	0.28	0.15	0.01

[a] Means are based on 6 replicates of 20 leaves per tree.
[b] Means in the same column followed by the same letter are not significantly different at the P=0.05 level using Duncan's NMRT.
[c] Applied with a high pressure handgun at 800 gal/acre.

Table 4. Mean number of active stages of predatory arthropods per leaf[a], Kern County, CA., 1983[b].

	Material	Rate (ai/100 gal)[c]	Sample Date 8-3-83			
			Phytoseiidae	Scolothrips sexmaculatus	Stethorus sp.	Chrysopa sp.
1.	415 NR Oil	1 qt/100 gal	0.07 b	0.5 a	0.06 a	0.04 a
2.	MK-936 0.15EC + 415 NR Oil	0.4 oz 1 qt/100 gal	0.03 b	0.16 bc	0.03 a	0.03 ab
3.	MK-936 0.15EC + 415 NR Oil + Ambush 2E	0.4 oz 1 qt/100 gal 0.2 lb	0.02 b	0.2 bc	0.03 a	0.025 abc
4.	NC-21314 50SC	0.5 lb	0.05 b	0.4 ab	0.04 a	0.0 c
5.	NC-21314 50SC + Triton AG98	0.5 lb 59 ml/100 gal	0.04 b	0.26 abc	0.05 a	0.0 c
6.	NC-21314 50SC + Plictran 50WP	0.5 lb 1.0 lb	0.0 b	0.03 c	0.0 a	0.01 bc
7.	Mavrik 2EC	0.1 lb	0.04 b	0.03 c	0.04 a	0.01 bc
8.	Mavrik 2F	0.1 lb	0.01 b	0.08 c	0.03 a	0.01 bc
9.	FMC-54800 2EC	0.06 lb	0.0 b	0.08 c	0.01 a	0.0 c
10.	FMC-54800 2EC	0.1 lb	0.02 b	0.02 c	0.0 a	0.0 c
11.	SC-1069 4EC	2.0 lb	0.0 b	0.04 c	0.0 a	0.0 c
12.	S-3206 2.4EC	0.2 lb	0.04 b	0.13 bc	0.06 a	0.017 abc
13.	Omite 30WP	3.0 lb	0.0 b	0.08 c	0.03 a	0.017 abc
14.	Water	--	0.23 a	0.40 ab	0.12 a	0.03 ab
Column Means			0.04	0.17	0.03	0.01

[a] Means are based on 6 replicates of 20 leaves per tree.
[b] Means in the same column followed by the same letter are not significantly different at the P=0.05 level using Duncan's NMRT.
[c] Applied with a high pressure handgun at 800 gal/acre.

Table 5. Mean number of active stages of predatory arthropods per leaf[a], Kern County, CA., 1983[b].

	Material	Rate (ai/100 gal)[c]	Sample Date 8-17-83			
			Phytoseiidae	Scolothrips sexmaculatus	Stethorus sp.	Chrysopa sp.
1.	415 NR Oil	1 qt/100 gal	0.008 a	0.0 b	0.017 a	0.0 a
2.	MK-936 0.15EC + 415 NR Oil	0.4 oz 1 qt/100 gal	0.008 a	0.0 b	0.008 a	0.0 a
3.	MK-936 0.15EC + 415 NR Oil + Ambush 2E	0.4 oz 1 qt/100 gal 0.2 lb	0.0 a	0.008 b	0.008 a	0.0 a
4.	NC-21314 50SC	0.5 lb	0.0 a	0.025 b	0.0 a	0.0 a
5.	NC-21314 50SC + Triton AG98	0.5 lb 59 ml/100 gal	0.008 a	0.0 b	0.0 a	0.0 a
6.	NC-21314 50SC + Plictran 50WP	0.5 lb 1 lb	0.0 a	0.03 b	0.0 a	0.0 a
7.	Mavrik 2EC	0.1 lb	0.09 a	0.39 a	0.008 a	0.0 a
8.	Mavrik 2F	0.1 lb	0.08 a	0.21 ab	0.008 a	0.0 a
9.	FMC-54800 2EC	0.06 lb	0.03 a	0.07 b	0.017 a	0.008 a
10.	FMC-54800 2EC	0.1 lb	0.04 a	0.03 b	0.0 a	0.008 a
11.	SC-1069 4EC	2.0 lb	0.0 a	0.025 b	0.008 a	0.0 a
12.	S-3206 2.4EC	0.2 lb	0.0 a	0.18 b	0.0 a	0.0 a
13.	Omite 30WP	3.0 lb	0.0 a	0.0 b	0.0 a	0.0 a
14.	Water	--	0.03 a	0.08 b	0.0 a	0.008 a
Column Means			0.021	0.074	0.005	0.002

[a] Means are based on 6 replicates of 20 leaves per tree.
[b] Means in the same column followed by the same letter are not significantly different at the P=0.05 level using Duncan's NMRT.
[c] Applied with a high pressure handgun at 800 gal/acre.

EFFECTS OF FOUR PESTICIDES ON ALMOND LEAF PHYSIOLOGY

R. R. Youngman and M. M. Barnes

The "Riverside" dual-isotope porometer was used to evaluate the effects of four pesticides and a water check on almond leaf physiology. This experiment was conducted in an orchard located in Kern Co. during the summer of 1983. The following materials were tested: Ambush 2E, Avermectin 0.15EC, Guthion 50W and Omite 30W. Additionally, there were two treatment combinations of Ambush plus Omite, and Guthion plus Omite. With the exception of the experimental material Avermectin, all of the treatments were selected on the basis of their actual or potential widespread use.

Materials and Methods

The orchard used in this trial consisted of third-leaf Nonpareil-variety almonds which were drip-irrigated. The experimental plot was located 3.2 miles east of Hwy. 99 and 1 mile north of Kimberlina road in Kern Co. A randomized block design, replicated four times, was used in assigning the treatments. All materials were applied until run-off, using a high pressure handgun with a #8 disc. The trees had not begun to develop any appreciable mite populations when the materials were applied on June 3, 1983. The single spray application was chosen to reflect the low frequency of pesticide applications almond orchards receive under current conditions. Typically insecticides are

applied only once or twice during the season, and which may or may not include an acaricide. Later in the season, prior to harvest, a second acaricide spray may be applied.

Porometer samples were taken between 9:30 am and 12:00 pm at three, ten and twenty days postspray to detect any possible latent effects caused by the treatments. All seven porometer measurements were made on leaves in direct sunlight from the southeast quadrant of the tree. The three physiological parameters evaluated in this study were: stomatal conductance to water vapor, mesophyll conductance to CO_2, and total stomatal conductance to CO_2 represented as photosynthesis.

Results and Discussion

A two-way analysis of variance was performed on the raw porometer data for each of the three postspray sample dates. No significant differences between treatments were found ($P<0.05$) for any of the sample dates (Table 1).

It may be concluded from this test, that one application of any of the above treatments will result in no significant changes to almond leaf physiological processes for up to twenty days thereafter.

Table 1. Effect of selected pesticides on three physiological parameters of "Nonpareil" almond leaves, Kern Co. 1983.

		3 days postspray[1]			10 days postspray			20 days postspray		
	Treatments[2]	C_s[3]	C_m[4]	Photosynthesis[5]	C_s	C_m	Photosynthesis	C_s	C_m	Photosynthesis
1.	Ambush 2EC[6]	0.840 a	0.571 a	49.82 a	0.826 a	0.614 a	52.24 a	0.830 a	0.406 a	42.51 a
2.	Ambush 2EC + Omite 30W	0.846 a	0.553 a	49.41 a	0.788 a	0.597 a	50.35 a	0.829 a	0.392 a	41.65 a
3.	Avermectin 0.15EC	0.784 a	0.592 a	49.02 a	0.773 a	0.635 a	50.26 a	0.789 a	0.416 a	41.66 a
4.	Guthion 50W	0.813 a	0.580 a	48.96 a	0.802 a	0.580 a	49.81 a	0.871 a	0.429 a	44.58 a
5.	Guthion 50W + Omite 30W	0.773 a	0.577 a	48.00 a	0.720 a	0.619 a	48.14 a	0.780 a	0.414 a	41.57 a
6.	Omite 30W	0.812 a	0.618 a	50.81 a	0.789 a	0.639 a	51.62 a	0.830 a	0.431 a	43.78 a
7.	Water	0.779 a	0.569 a	48.02 a	0.768 a	0.597 a	48.89 a	0.819 a	0.424 a	43.26 a

1 Means are averages of four single-tree replicates (7 subsamples per tree). Means within a column followed by the same letter are not significantly different at P=0.05 using Duncan's NMRT.

2 Treatments were applied on June 3, 1983 with a high pressure handgun.

3 C_s = stomatal conductance to H_2O in units of cm/sec.

4 C_m = mesophyll conductance to CO_2 in units of cm/sec.

5 Photosynthesis is in units of $mgCO_2\ dm^{-2}h^{-1}$.

6 The rates in a.i./acre for Ambush, Avermectin, Guthion and Omite are respectively: 0.2 lbs, 0.8 oz, 2.0 lbs, 3.0 lbs.

IN-SEASON PERMETHRIN SPRAYS AND SUBSEQUENT EARLY-SPRING SPIDER-MITE POPULATIONS

J. P. Sanderson and M. M. Barnes

Many growers have reported early-season spider mite problems on trees which had been treated with permethrin (Ambush or Pounce) for navel orangeworm control in the previous year. In the 1982 Annual Report, we documented that high spider mite populations developed on almond trees shortly following sprays of permethrin (Ambush) at hullsplit. These same trees were observed from March to June of 1983 to note the levels of both spider mites and predaceous mites present during this time.

Methods and Materials

Nonpareil almond trees in an unsprayed, 9 year-old orchard located ca. 4 mi. north of Shafter, Kern County, were sprayed on 7/16/82. Three spray treatments (Ambush 2.0EC at 0.2 lb ai/acre; Ambush 2.0EC plus Omite 30WP at 0.2 and 3.0 lbs ai/acre, respectively; and Guthion 50WP plus Omite 30WP at 2.0 and 3.0 lbs ai/acre, respectively) plus an unsprayed check were replicated 6 times in a randomized block design using single-tree replicates. The experimental trees were spaced 3 trees apart to allow for an unsprayed zone between trees.

Twenty leaves were sampled from near the crotch of each of the trees on 3/28/83. Samples were also collected from each tree at eye-level by picking

5 leaves from each of the 4 compass quadrants, including leaves from the inside and outside of each quadrant, for a total of 20 leaves per tree. The eye-level samples were collected on 3/28, 4/18, 5/16, and 6/3. Using a dissecting microscope, the numbers of active stages of spider mites and predaceous mites were recorded for all samples.

Due to the variability in sample counts, the raw data was first transformed using a log transformation, and then analyzed for significance by using a 2-way analysis of variance.

Results and Discussion

The levels of both spider mites and predaceous mites on the leaves sampled from the crotch of the trees on 3/28/83 are shown in Table 1. Significantly higher spider mite levels were found on the trees which had been sprayed in 1982 with either of the treatments containing permethrin, when compared to the Guthion plus Omite treatment or the unsprayed check. The Ambush plus Omite treatment was not statistically different from the treatment containing Ambush alone. Therefore, the addition of an acaricide did not make a significant difference in the subsequent year's spider mite levels. The trees treated with Guthion plus Omite did not have statistically different spider mite levels than those of the unsprayed trees. The predaceous mite levels were not significantly different between any of the treatments.

The average number of spider mites and predaceous mites per leaf from the samples collected at eye-level are presented in Tables 2 and 3, respectively. The trees sprayed with the treatments containing permethrin consistently had higher spider mite levels than the other trees for all the sample dates (Table 2). Again, these data indicate that the addition of an acaricide did not make a significant difference in the spider mite levels in 1983

on the trees sprayed with permethrin in 1982. The data in Table 3 indicate that no significant difference existed in the levels of predaceous mites between the 4 treatments, with the exception of the samples taken on 5/16/83. From these data, it appears that the levels of predaceous mites had little to do with the early-season spider mite levels on the Ambush-sprayed trees.

The experimental trees were again observed in early August, although no samples were taken. Both spider mites and predaceous mites were uncommon on any of the trees at this time. This orchard has not received any in-season sprays for 3 years, and spider mites were not a problem in this orchard in 1983. Therefore, there was probably a good resource of beneficial arthropods present in the orchard, which reduced the spider mite levels on the experimental trees between June and August.

In summary, it appears that a single spray of permethrin at hullsplit can lead to higher early-season mite populations in the next year, even if an acaricide is included in the hullsplit spray. A lack of predatory mites doesn't appear to be the major cause of these early spider mite levels. The exact relationship between applications of permethrin and subsequent early-season spider mite populations has yet to be determined.

Table 1. Average number of active stages of spider mites and predatory mites on leaves sampled from the crotch of Nonpareil trees in March, 1983.

Treatment	Ave. No. Spider Mites per Leaf [a,b]	Ave. No. Predatory Mites per leaf [b,c]
Ambush + Omite	2.57 a	0.10
Ambush	1.58 a	0.40
Guthion + Omite	0.42 b	0.18
Check	0.02 b	0.0

a Means in the same column followed by the same letter are not significantly different at the P=0.05 level using Duncan's NMRT.

b Based on 20 leaves from the crotch of each of 6 trees per treatment.

c Analysis of variance produced a non-significant F-value.

Table 2. Average number of active stages of spider mites per leaf[a], Shafter, 1983[b].

Treatment[c]	Sample Date 3/28	4/18	5/16	6/3
Ambush + Omite	0.31 a	1.85 a	1.22 a	2.43 a
Ambush	0.13 ab	1.79 a	1.11 a	1.46 a
Guthion + Omite	0.0 b	0.10 b	0.08 b	0.07 b
Check	0.0 b	0.0 b	0.0 b	0.0 b

a Based on 20 leaves per tree, 6 trees per treatment.

b Means in the same column followed by the same letter are not significantly different at the P=0.05 level using Duncan's NMRT.

c Sprays were applied on 7/16/82 with high pressure handgun.

Table 3. Average number of active stages of predaceous mites per leaf[a], Shafter, 1983[b].

Treatment[c]	Sample Date 3/28	4/18	5/16	6/3
Ambush + Omite	0.0	0.03 a	0.10 a	0.03 a
Ambush	0.0	0.02 a	0.08 a	0.01 a
Guthion + Omite	0.0	0.08 a	0.01 b	0.0 a
Check	0.0	0.0 a	0.01 b	0.02 a

a Based on 20 leaves per tree, 6 trees per treatment.

b Means in the same column followed by the same letter are not significantly different at the P=0.05 level using Duncan's NMRT.

c Sprays were applied on 7/16/82 with high pressure handgun.

CONTINUING INVESTIGATIONS INTO THE INTERACTION OF SPIDER MITE FEEDING AND WATER-STRESS ON FOURTH-LEAF ALMOND TREES

R. R. Youngman and M. M. Barnes

The 1982 spider mite and water-stress experiment demonstrated that the combination of both stresses resulted in a greater degree of suppression in both photosynthetic and stomatal conductance rates than either stress alone. Based on these results, it was necessary to proceed further with this study in 1983.

The 4 treatments used in the 1983 experiment were the same as in 1982. Treatments 1 and 2 received water throughout the trial, while treatments 3 and 4 were kept water-stressed. Additionally, spider mite populations were allowed to build on treatments 2 and 4.

One modification to the 1983 experiment was to allow the mite population to attain a certain density on treatments 2 and 4 prior to the start of the water-stress period. Upon reaching that density, the mites were sprayed out, and the period of water withdrawal was begun. This enabled us to fix the mite-injury component equally between treatments 2 and 4, allowing only the component due to water-stress to vary during the course of the experiment. Because of this modification, it was not possible to study the impact of water-stressed leaves on spider mite density.

Materials and Methods

The orchard used in this study is located near the east side of Hwy. 99 and about one-half mile south of Merced Ave. The Minnehoma Land and Farming Company generously loaned the almond trees used in this experiment.

The test plot consisted of a single row of 4th-leaf Nonpareils and was located four rows in from the east side of the orchard. The other two varieties present in the orchard were Carmel and Jeffries and the row-tree spacing was 24 X 20 feet.

A randomized block design, replicated six times, was used to assign the treatments. All of the six blocks contained one replicate of each of the four treatments and were located within the single row. A buffer tree (which was water-stressed) was used to separate a non-water-stressed from a water-stressed tree. Buffer trees were kept free of mites throughout the experiment.

The orchard is under a drip irrigation system where each tree receives water from two drip emitters attached to a flexible hosepipe. This hosepipe is placed next to the tree's base and extends along the entire length of the row. A tree was water-stressed by simply replacing both drip emitters at its base with standard plugs.

A Pacific spider mite colony, maintained on Sieva lima beans in the greenhouse at UCR, was used to infest the almond trees in treatments two and four. This was done on a weekly basis from May 23 to June 22. At the same time, weekly leaf samples from all twenty-four trees were taken to follow the mite population. Six leaves were randomly removed from each of the four cardinal-point-facing quadrants, making up a total sample size of twenty-four leaves per tree. All leaf samples were kept refrigerated until they

could be observed under a dissecting microscope, at which time all motile mite stages were counted.

Ten male spider mites from the June 21 sample were identified from slide mounts. Eight were determined to be the Pacific spider mite, Tetranychus pacificus, one was the twospotted spider mite, Tetranychus urticae, and the other was Tetranychus turkestani.

On June 22, the acaricide Omite 30W was applied at a rate of 3 lbs a.i. per acre to the trees in treatments 1 and 3 which were to be kept mite-free. On July 6, all trees (including those sprayed on June 22) were sprayed with Omite 30W since the desired spider mite density was reached on the mite-infested trees.

Measurements of leaf water potential were taken every seven days from 12:30 to 2:00 pm to establish the level of water-stress. Four leaves per tree were randomly selected at eye level from each of the cardinal point quadrants. A reading was made on each leaf with a PMS pressure bomb as soon as it was removed from the tree. Pressure bomb readings began on July 8 and continued through August 12.

The "Riverside" dual-isotope porometer was used to quantify the interaction effects of mite feeding damage and water-stress on photosynthesis and stomatal conductance to water. Seven samples per tree were taken weekly from 9:30 to 11:45 am on the same dates that the pressure bomb readings were taken. These porometer samples were taken on leaves in direct sunlight located on the south-east side of the tree.

Measurements taken with the "Riverside" dual-isotope porometer describe two important leaf gas exchange parameters: stomatal conductance to water vapor and photosynthesis. Stomatal conductance can be defined as the resistance water vapor encounters as it moves from the substomatal cavity past

the guard cells to the outside air layer. On the other hand, photosynthesis is based on the total stomatal conductance of CO_2 into the leaf; including its fixation into the first products of photosynthesis which occurs in the mesophyll cells.

The immediate effect of water-stress is to restrict the stomatal opening preventing further loss of water vapor. This also reduces the diffusion rate of CO_2 molecules into the stomata resulting in a lower photosynthetic rate. This trend can be reversed if normal water relations are restored to the tree prior to reaching the permanent wilting point. Irreversible damage to almond leaves results from any physical injury such as that which is due to leaf abrasion or feeding by spider mites. This is because the leaf lacks meristematic tissue which is necessary to replace damaged cells.

Results and Discussion

Unless otherwise noted, a two-way analysis of variance was used to analyze all data collected at each date during the summer of 1983. Also, in the following discussion, all significant differences found between treatments are considered at the $P<0.05$ probability level. Table 1 serves as a guide for identifying the four treatments referred to below by numbers 1-4. Table 2 presents the actual mean values for both stomatal conductance and photosynthesis in addition to the statistical analysis of the four treatments. The pressure bomb data is presented in Fig. 1, and Figures 2 and 3 are graphs of stomatal conductance and photosynthesis, which represent the treatment means as relative percent of the control (treatment 1).

A mite-day is defined as one mite feeding for one day and incorporates both aspects of density and duration of an infestation. The total number of mite-days accumulated by July 6 in treatments 2 and 4 were 311.2 and 303.3

respectively. These values were not significantly different as determined by a twosample t-test.

Referring to the pressure bomb data in Fig. 1, the solid line represents the control which consists of the data from treatments 1 and 2. Treatments 1 and 2 received water on a regular basis during the course of the experiment. The dashed line consists of the data from treatments 3 and 4, which were water-stressed. Since no statistical differences could be detected between the two mite levels within a water level, the data were lumped. Why this occurred is not entirely clear; it may be that the pressure bomb is not a sensitive enough device to detect differences imposed by the level of mite damage present in this experiment. In referring to Fig. 1, we were able to obtain two separate periods of water withdrawal. This was because the trees became rapidly water-stressed within just a few days after water deprivation. By July 15 the water-stressed trees were visibly wilted and by July 22 it became necessary to restore water to those trees to prevent permanent damage and heavy leaf drop. On July 29, after one week of normal irrigation, the leaf water potential of the previously water-stressed trees was very close to their July 8 level. The water was left on until August 3 at which time it was cut off again to repeat the water-stress cycle.

It should be noted that the two lines in Fig. 1 are statistically separate at every sample date. This heterogeneity between the treatments was not felt to be serious; it primarily resulted in an acceleration of the differences between the two water treatment levels as evidenced through time.

Treatment 2 which was not water-stressed, reflects the separate impact of mite feeding injury on stomatal conductance and photosynthesis (Figs. 2 and 3). With the exception of the July 15 and August 5 sample dates, treatment 2 was significantly lower than the control on all sample dates. Overall,

this represents a reduction in stomatal conductance and photosynthesis of about 15 and 18 percent from their respective controls.

With respect to treatments 3 and 4, the physiological measurements taken on July 15, 22 and August 12, reveal little information other than the extremely severe impact of water-stress on the inhibition of stomatal conductance and photosynthesis. This condition was responsible for masking the effect of the mite damage component, resulting in the non-significant separation evident on those dates (Table 2).

The impact of water-stress on stomatal conductance and photosynthesis was much less severe on the July 8, 29 and August 5 sample dates. Because of this, the addition of the mite-damage component could be detected (treatment 4). In considering the July 8 and July 29 dates, treatment 4 was found to cause significantly lower stomatal conductance rates than the other three treatments. On August 5, treatments 3 and 4 were not statistically different from each other, but were significantly lower than treatments 1 and 2.

The effect of treatment 4 on photosynthesis (Fig. 3) was similar to that which occurred on stomatal conductance for the same dates. Treatment 4 caused significantly lower readings than the other three treatments with the exception of treatment 2 on July 8. Apparently the level of water-stress present by July 8 was not severe enough to cause a statistical separation between treatments 2 and 4.

Conclusions

The results of the past two summers' research were found to be in agreement on the relationship of both stresses to almond leaf gas exchange processes. The combined action of both stresses (treatment 4), almost always resulted in the most significant reduction in stomatal conductance and

photosynthesis. The exception to this occurred when water-stress had become particularly severe. At severe water-stress levels, stomatal conductance and photosynthesis were reduced by as much as 81 and 78 percent respectively. Trees which have been maintained on a proper water schedule appear to be able to tolerate up to 100 accumulated mite-days (1982 Almond Board) with little or no impact on leaf gas exchange processes. When higher mite levels have been reached, e.g., 200-300 mite-days (1982-83 Almond Board), any significant drop in leaf water potential results in a dramatic reduction in these same processes.

Most almond orchards are subjected to some degree of water-stress to accommodate harvest practices. This occurs during the time of year when extreme summer temperatures can rapidly deplete the soil moisture content. Additional evidence (1982 Almond Board) indicates that significantly higher spider mite densities occur on water-stressed almond trees. Together, all of these factors can result in significant yield reductions; in addition to an impairment of the tree's overall growth and vigor for the following year. The key to minimizing these effects lies in proper mite and soil management. Considering one without the other can have serious consequences for almond production.

Table 1. A guide to treatments 1-4.

Treatment No.	Treatment Description
1	Regular water schedule - mite feeding injury
2	Regular water schedule + mite feeding injury
3	Water-stress schedule - mite feeding injury
4	Water-stress schedule + mite feeding injury

Table 2. Effects of mite feeding injury and water-stress on two physiological parameters of "Nonpareil" leaves, Kern Co. 1983.

Sample Date	Treatment No.	Stomatal[1] Conductance to THO (cm/sec)	Photosynthesis ($mgCO_2dm^{-2}h^{-1}$)
7-8	1	0.622 a[2]	37.363 a
	2	0.525 b	29.289 b
	3	0.549 ab	34.371 a
	4	0.429 c	25.348 b
7-15	1	0.690 a	38.766 a
	2	0.659 a	34.881 a
	3	0.096 b	7.990 b
	4	0.084 b	6.927 b
7-22	1	0.745 a	37.772 a
	2	0.576 b	30.830 b
	3	0.082 c	7.051 c
	4	0.087 c	7.094 c
7-29	1	0.756 a	36.588 a
	2	0.658 b	31.491 b
	3	0.722 ab	35.408 a
	4	0.572 c	28.037 c
8-5	1	0.629 a	32.500 a
	2	0.527 a	27.030 a
	3	0.289 b	19.433 b
	4	0.220 b	13.295 c
8-12	1	0.456 a	27.431 a
	2	0.371 b	21.415 b
	3	0.086 c	6.903 c
	4	0.085 c	6.070 c

1 Means of six single-tree replicates (seven subsamples per tree).

2 Means within a column followed by the same letter are not significantly different at P=0.05 using Duncan's NMRT.

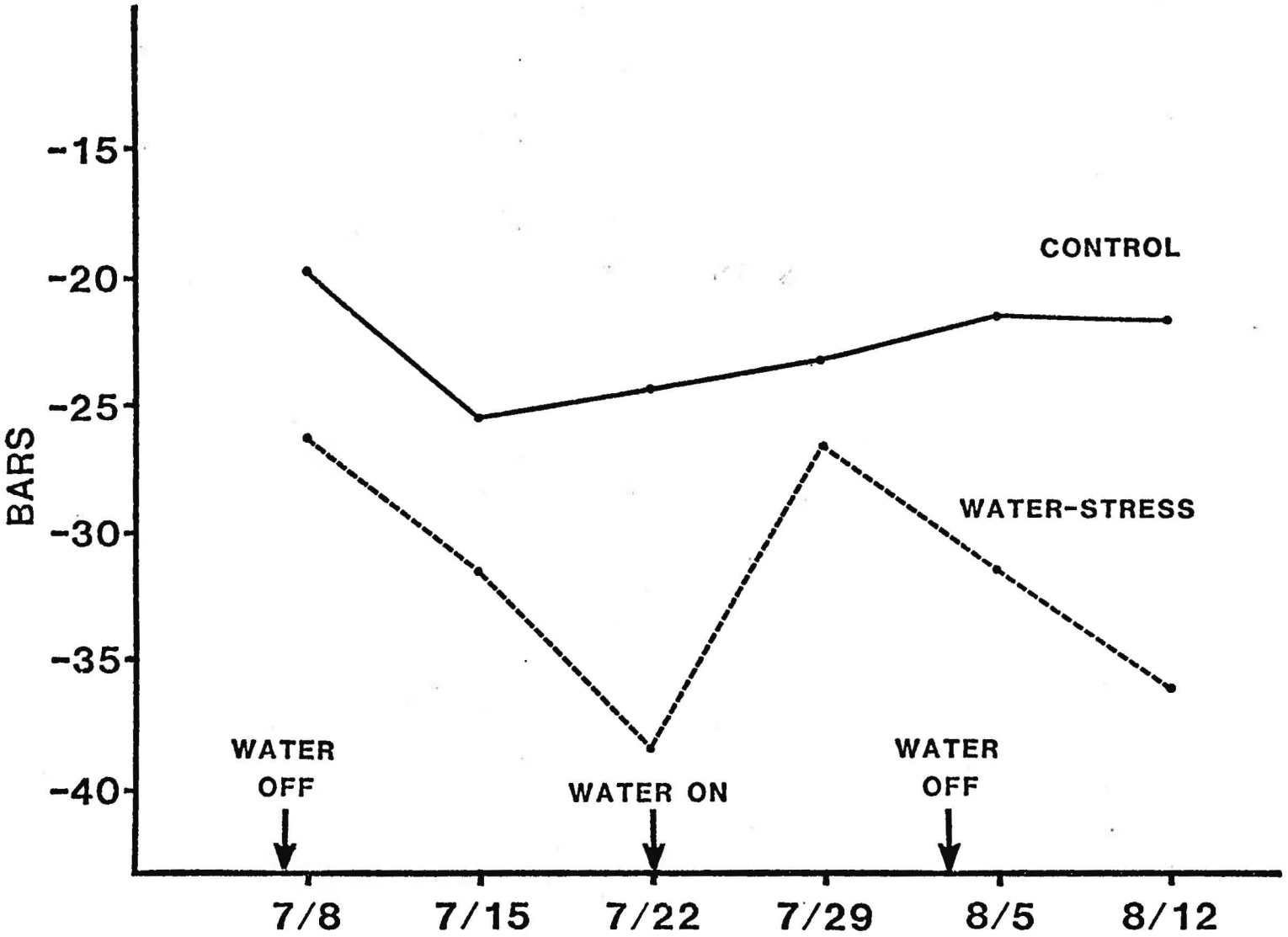

Fig. 1. Leaf water potential (Bars) in water-stressed vs. non-water-stressed almonds.

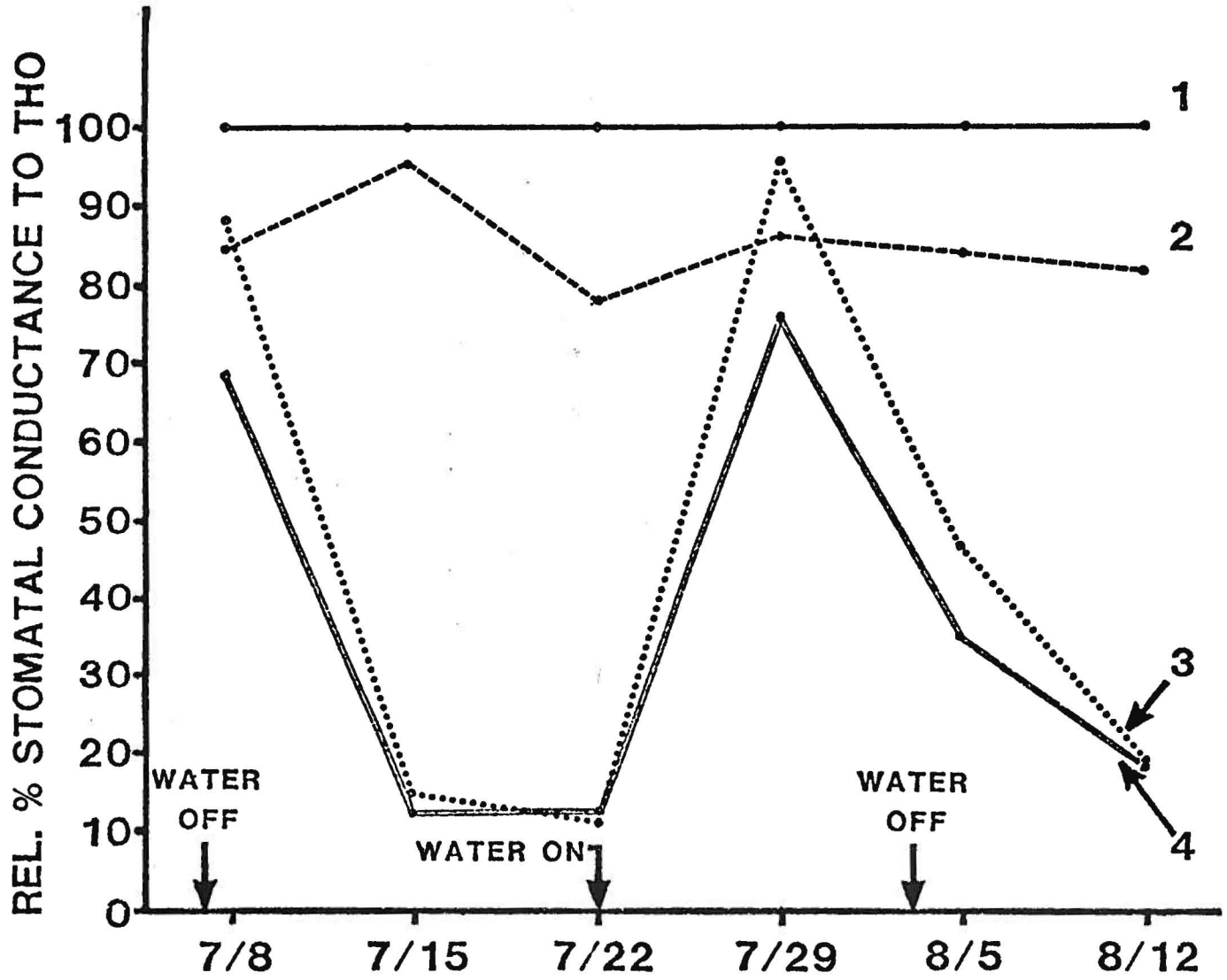

Fig. 2. Stomatal conductance (THO) rates of all treatments relative to the control.

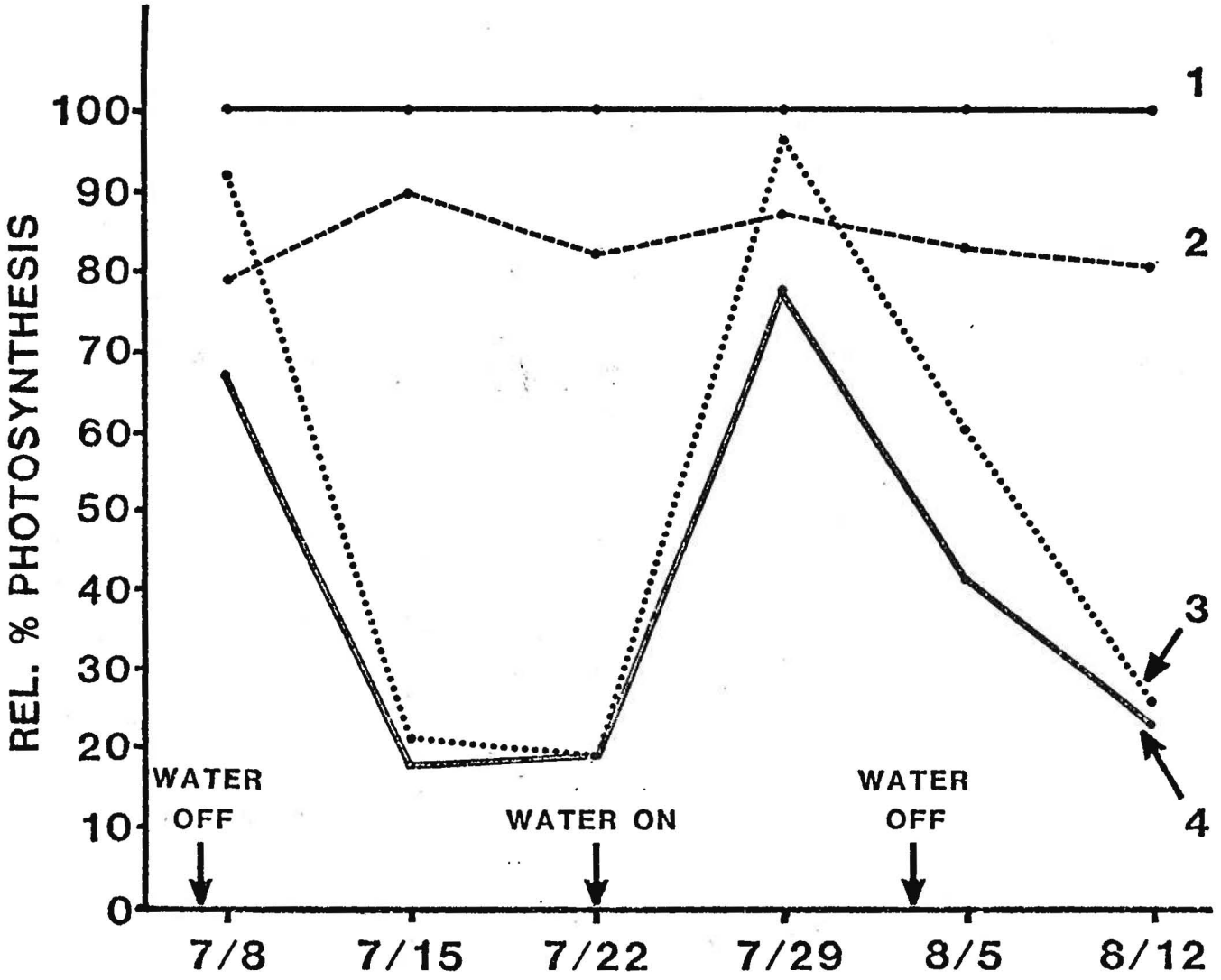

Fig. 3. Photosynthetic rates of all treatments relative to the control.

A COMPARISON OF THE PHYSIOLOGICAL EFFECTS OF FEEDING INJURY CAUSED BY FOUR TETRANYCHID MITE SPECIES ON ALMONDS

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The extent, if any, to which spider mite species differ in their ability to damage a host is important information for pest management. Such information should be taken into consideration when devising a sampling plan or determining an economic threshold for mites on crops where more than one species may occur. The hypothesis tested in this experiment is that a difference in feeding injury exists between mite species on almond leaves. This experiment consisted of five treatments - four of which were feeding injury by the following spider mites: the citrus red mite, Panonychus citri; the European red mite, P. ulmi; the Pacific spider mite, Tetranychus pacificus; and the twospotted spider mite, T. urticae. The fifth treatment was a mite-free control. The mites were placed on leaves of one year old Mission variety trees grown in the greenhouse at UCR.

Materials and Methods

The six trees used in this experiment were uniform in size and shape and in good condition. Each tree served as a block within which the five treatments (including five subsamples per treatment) were randomly assigned.

An arena was used to confine the individuals of each species to an area

of 3.24 cm^2 on the upper leaf surface. The arenas were made from three layers of masking tape which was used to stick them to the leaf. A bead of vaseline petroleum jelly was placed on top of the tape which served as a barrier to prevent mite escape. Six adult female mites were placed in each arena between 2:00 and 4:00 pm on June 8, and were checked daily to replace any mites which became stuck or had fallen off. After seven days, all mites were removed from the arenas with a damp sponge. It should be noted that this is approximately equivalent to 47 mites per leaf, or 319 total accumulated mite-days. This is based on the average total surface area of 25.54 cm^2 determined from forty Mission variety leaves, collected off ten year old trees.

On June 16, all trees were moved out of the greenhouse, placed in direct sunlight and watered. The trees were allowed to equilibrate to the outside environment from 8:30 to 11:30 am, at which time physiological measurements were taken with the "Riverside" dual-isotope porometer.

There are three basic leaf gas exchange parameters considered in this study: the first is stomatal conductance to water vapor which can be defined as a measurement of the resistance water vapor encounters as it moves past the guard cells to the external environment. The second parameter is mesophyll conductance and can be defined as the resistance CO_2 encounters as it moves from the substomatal cavity into the mesophyll cells. The third parameter is photosynthesis and is based on the total conductance of CO_2 which consists of the stomatal conductance of CO_2 past the guard cells plus mesophyll conductance to CO_2. Definitions are based in part on LaPre et al., J. Econ. Entomol. 75: 616-619 (1982).

Results and Discussion

The treatment means for each variable are presented in Table 1. A two-

way analysis of variance was performed on the raw data, and the treatments proved to be significantly different ($P < 0.05$) for all three variables. The Pacific spider mite, T. pacificus, caused significantly lower stomatal conductance rates when compared to the control, P. citri and P. ulmi. In regard to mesophyll conductance and photosynthetic rates, injury by T. pacificus was significantly lower than that caused by P. citri, but not that due to P. ulmi or T. urticae.

One explanation why almond leaves are least damaged by citrus red mite feeding may be that they are a poor alternate food source. Unlike the other three species, P. citri does not undergo diapause and must rely on citrus - its primary host - to overwinter. Citrus red mite infestations in almond orchards usually only occur when susbtantial citrus plantings are nearby.

Table 1. Comparison of the effect of feeding injury by four spider mite species on three physiological parameters on "Mission" almond leaves.

Treatment	Stomatal[1] Conductance to THO (cm/sec)	Mesophyll Conductance to $^{14}CO_2$ (cm/sec)	Photosynthesis ($mgCO_2\ dm^{-2}h^{-1}$)
Control	0.987 (100) a[2]	0.236 (100) a	31.430 (100) a
Panonychus citri	0.901 (91.3) b	0.225 (95.5) ab	29.647 (94.3) ab
Panonychus ulmi	0.896 (90.7) b	0.207 (87.7) bc	27.910 (88.8) bc
Tetranychus urticae	0.838 (84.9) bc	0.202 (85.5) bc	26.922 (85.7) bc
Tetranychus pacificus	0.788 (79.9) c	0.190 (80.4) c	25.351 (80.7) c

1 Means of six single-tree replicates (five subsamples per tree), followed by percent of control in parenthesis.

2 Means within a column followed by the same letter are not significantly different at P=0.05 using Duncan's NMRT.