84-D11

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Project Leader: M. M. Barnes

Investigations on Navel Orangeworm and Mites in Almond Orchards

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Summary of Principal Results, 1984

Project No. 84-D11 - Navel Orangeworm, Mite and Insect Research
Insecticides and Mite Studies

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Objectives: (1) Develop specific NOW management procedures for later maturing pollinizer varieties like Merced. This will include further insecticide development. (2) Continue development of miticides. (3) Continue to determine the upper developmental temperature ceiling for NOW as input into the simulation model. (4) Determine the utility of NOW day-degree development in mummies as a means of timing hullsplit sprays. (5) Determine the necessity of grounded mummy destruction when low levels of tree mummies are reached. (6) Develop information on the carob moth which can be used for its management and control (funded by the California date industry).

Interpretive Summary: (1) Both Lorsban WP and Guthion WP suppressed UV trap catches of NOW moths for 10 days, when applied by ground at Nonpareil hullsplit. Results on Merceds suggest that Lorsban should be applied by ground rather than by air at Merced hullsplit. Results of larvicidal trials with new compounds and formulations for NOW indicate that Larvin should be used at 2 lb ai/acre, that FMC-54800 should be applied at 0.15 lb/acre, as compared with 0.075 lb/acre, and that the EC formulation of Ambush is more effective than the WP. (2) Results of a miticide trial showed that FMC-54800 initially reduced spider mite and predator populations (predominantly sixspotted thrips); however, mite resurgence was evident at the end of the 2nd week after treatment. Larvin did not affect spider mites or sixspotted thrips. (3) Laboratory studies to explore the upper developmental threshold of various stages of the navel orangeworm will be resumed this winter. (4) We have tested our degree-day information for navel orangeworm development on both mummy and new crop almonds against field observations from several years and regions of the Central Valley, with good results. Degree-day development in mummies might be used to time a hullsplit spray in those rare years when the 2nd flight of the NOW occurs well after hullsplit initiation. In these years, a spray applied at hullsplit initiation may be too early for optimum NOW control and crop protection. However, in most years the 2nd flight occurs prior to or concurrent with hullsplit initiation, and a spray timed at hullsplit initiation is optimal. We have developed recommendations for the use of degree-days to predict the start of the 3rd NOW flight. (5) Due to logistic and communication problems, the grounded mummy almonds in all the experimental plots were destroyed, preventing execution of this study. (6) Using various stages of the carob moth from the Riverside laboratory colony, collaborating USDA entomologists have determined methyl bromide fumigation effects, using a trailer unit. (7) Data from new-crop almonds in 1983 and 1984 indicate that the navel orangeworm required only 5 larval instars to complete development, compared to a requirement of 6 instars on mummy almonds. This correlates well with the greater average degree-day accumulation required for development on mummies (1125°D) than on new-crop almonds (766°D). (8) A study was conducted which confirmed the use of almond presscake-baited egg traps to detect the beginning of the 3rd NOW flight. (9) Why are spider mites a more severe pest in some orchards and in some years, quite apart from the influence of predators or pesticides? We are investigating this spider mite/almond tree relationship: mites do not lay more eggs when on water-stressed leaves; the latter can be much warmer (9°F) than unstressed leaves, depending on prevailing temperature.

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Insecticides for Navel Orangeworm

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

Results of a trial comparing different compounds, rates and formulations for navel orangeworm are presented in Table 1. These results suggest that FMC 54800 EC at 0.15 lb per acre is equivalent to Ambush EC at 0.10 lb and the emulsified formulation of Ambush was superior to the wettable powder. Larvin should be applied at 2 lb ai per acre, to judge from results of previous years. In an associated trial with Larvin reported elsewhere herein, this compound was shown not to interfere with heavy mite predation by sixspotted thrips. Guthion gave its usual performance, in small scale trials like this one, of 40-50% control.

Table 1. Results of experiment on the efficacy of insecticides used for navel orangeworm control on Nonpareil almonds, Kern Co., 1984.

Treatment	Formulation	Lb ai/acre[a]	Average % damage at harvest[b]		
				P = 0.05	P = 0.1
Ambush	2.0EC	0.10	3.6	a	a
Ambush	25WP	0.20	4.2	a	a b
FMC 54800	2.0EC	0.15	4.7	a b	a b
Guthion	50WP	2.00	5.1	a b	a b c
Ambush	25WP	0.10	5.2	a b	a b c
FMC 54800	2.0EC	0.075	5.6	a b	b c
Larvin	80DF	1.50	6.8	b	c
Untreated	-	-	8.9	c	d

[a] Applied (7/2/84) by handgun at 2% hullsplit in treetops; 800 gal per acre; 7 blocks of single tree replicates.

[b] Based on 300-nut samples taken from each tree; harvested 8/30/84.

[c] Averages in the same column followed by the same letter are not significantly different at indicated odds using Duncan's new multiple range test.

Comparison of Guthion and Lorsban at Nonpareil Hullsplit: plus Lorsban by air at Merced Hullsplit

M. M. Barnes and David H. Oi

Experimental data on use of Lorsban for navel orangeworm in almond orchards prior to 1983 was based on single tree replicated plots providing larvicidal action at hullsplit. Depending only on larvicidal action, early results showed that 4 lb active ingredient (ai) per acre would be required. In 1983, a 10-acre trial in spring showed that Lorsban WP at 2 lb ai/acre, applied by ground, provided rapid adult moth suppression as indicated by almost total immediate reduction in oviposition on egg traps. In such applications in the cool weather of spring, our results in 1983 and prior years have not shown suppression of adults by sprays of Guthion WP. We had not previously observed effects of Guthion on moths at the higher temperatures generally experienced at hullsplit.

Methods

In 1984, we sought to compare Lorsban WP and Guthion WP in relatively large plots by ground sprayer at Nonpareil hullsplit. As well, a similar block was treated by ground sprayer at Nonpareil hullsplit with Lorsban WP, followed by a helicopter application of Lorsban E just at initiation of Merced hullsplit, which came 24 days after Nonpareil hullsplit.

The trial was conducted in a mature 25-acre Nonpareil, Merced, Texas Mission orchard which had a significant load of soft shelled mummies present at hullsplit, ca. 5 per tree. This translated into a high potential infestation of the new crop from first generation moths emerging from mummies. A heavy population of web spinning mites was present requiring inclusion of a miticide. Each plot was ca. 8 acres in size. Treatment at initiation of hullsplit in tree tops was by speed sprayer at 2.5 mph, 250 gal per acre. The post hullsplit treatment was by helicopter at 30 gal per acre. Maximum orchard temperatures of the two-day period of treatment (7/3-7/4) were 99° and 96°F.

To observe effects on moth activity, 8-watt UV light traps were operated in the Guthion and Lorsban-Lorsban blocks and checked every other day. As well 8 black egg traps were operated in all 3 blocks, checked twice a week.

Results

Both Lorsban and Guthion (WPs) applied by ground at hullsplit strongly suppressed moth catch by UV light traps for 10 days. This result with Guthion contrasts with past experience in spring and may be related to the higher temperature prevailing.

Egg trap catches rose sharply in all plots 23-26 days after the hullsplit treatment. The helicopter application of Lorsban emulsifiable was made 21 days after the hullsplit treatment by ground and apparently delayed the onset of oviposition increase by no more than 2 days. There was no evidence that egg deposition was suppressed thereafter by this treatment. Either the emulsifiable formulation was poorly residual against moths or coverage by air was inadequate to effect residual suppression of moth activity. Results at harvest (Table 1) show that the single application of either Guthion or Lorsban WPs by ground at hullsplit gave equivalent control of navel orangeworm on Nonpareils in a heavy infestation. There was no significant improvement on Nonpareils by the additional air application of Lorsban E. The results on Merceds are partly inconclusive. The Merceds in blocks receiving a single treatment of either Lorsban or Guthion at Nonpareil hullsplit showed heavy equivalent infestations at harvest. The Merceds in the block treated again by air with Lorsban had a heavier infestation than the block treated only once, hence the inconclusive result.

It appears that full advantage of the shorter interval to harvest with Lorsban is best taken by using a wettable powder and ground application at Merced hullsplit.

Table 1. Comparison of Lorsban and Guthion, Kern Co., 1984.

Treatment	Formulation	Method of application	Active ingredient per acre	gal/acre	Harvest navel orangeworm (%) Nonpareil[3]	Merced[4]
1. Lorsban	50W	Ground[1]	2.0 lb	250	13.2 a	41.0 b
Lorsban	4E	Helicopter[2]	2.0 lb	30		
2. Lorsban	50W	Ground[1]	2.0 lb	250	14.7 a	29.0 a
3. Guthion	50W	Ground[1]	2.0 lb	250	12.8 a	25.8 a

[1] First application made at initiation of Nonpareil hullsplit 7/3-4.
Plus Plictran 50W 1 lb active ingredient per acre.
Plus Helena Buffer D.S. 1 pt/100 gal.
Plus No Foam B, 6 fl. oz/500 gal.

[2] Second application made at Nonpareil-hullsplit-plus-21 days, 7/24, which was at Merced hullsplit.
Plus Plictran 50W 0.86 lb active ingredient per acre.

[3] Samples taken 8/17, 300 nuts from each of 15 trees.

[4] Samples taken 8/20, 300 nuts from each of 12 trees.

The Use of Degree-Days to Predict

Second Generation Navel Orangeworm Adult Emergence

J. P. Sanderson and M. M. Barnes

Our project has made a considerable effort to develop a degree-day model which will predict emergence patterns of navel orangeworm adults. This information is useful in order to accurately time various management practices. The emphasis of the work in this report is the prediction of the beginning of emergence of the second generation adults (i.e. 3rd flight), which usually occurs just prior to Nonpareil harvest. The adults of the 2nd generation lay the eggs of the very damaging 3rd generation. However, the information which follows may also be applied to time management practices aimed at other generatiions of the navel orangeworm.

In the summers of 1981 and 1982, W. S. Seaman placed newly-hatched first-instar navel orangeworms into caged newly-hullsplit Nonpareil almonds, and determined the number of degree-days which accumulated during the development of each individual to the adult stage (1982 Annual Report). Degree-days were calculated using a lower developmental threshold of 55°F, and an upper threshold of 94°F, with a vertical cutoff. He then plotted the cumulative % emergence of the individuals from both years vs. accumulated degree-days (Fig. 1). Using fig. 1, it appears that individuals in a group of navel orangeworms which hatch from eggs laid on the same date on newly-hullsplit almonds will begin to emerge as adults after the accumulation of 600-650°D, and 50% of the individuals in the group will emerge by about 766°D (see also Table 1).

In the spring of 1982, Seaman conducted a similar field study using caged mummy almonds as a rearing substrate. Sanderson repeated the study in

1983 and 1984. Again, the number of degree-days which accumulated during the development of each individual was calculated. For each of these 3 studies, the cumulative % emergence is plotted vs. accumulated degree-days in fig. 2. It appears in fig. 2 that the first significant adult emergence from a group of navel orangeworm eggs laid on the same day on mummy nuts would occur after the accumulation of ca. 950°D. Fig. 2 and Table 1 show that 50% emergence (or average development) requires ca. 1125°D on mummy almonds.

In order to determine how to use this degree-day information to predict the beginning of the 3rd flight, data sets of navel orangeworm activity from several years and regions of the San Joaquin Valley were studied. The degree-day information adequately explained the observed beginning of the 3rd flight in all the data sets except one (Sprays may have influenced the results in the aberrant orchard). From these data sets, it appears that the biofix which must be used in order to detect the start of the 3rd flight depends in part on when the 2nd flight occurs in relation to hullsplit initiation. Three relationships can occur:

1. In most years, the bulk of the emergence of the 1st generation (2nd flight) occurs roughly concurrent with the start of Nonpareil hullsplit. Thus, the first eggs of the 2nd generation are laid on the first new-crop almonds which split; that is, the newly hullsplit almonds in the tree tops. Based on the degree-day information on new-crop almonds, the first adults which would develop from eggs laid at this time (i.e. tree-top hullsplit) would emerge no sooner than 600-650°D, and this is reasonably confirmed by several data sets.

2. In some years and in some areas, a large portion of the 2nd flight occurs early, i.e., more than 2 weeks prior to the start of hullsplit. Since at this time there are no hullsplit new-crop almonds, the eggs produced by

these moths must be laid on any mummy almonds which are present in the orchard. If the orchard has a high mummy load, then a significant part of the 2nd generation (3rd flight) may develop on these mummies. In a situation such as this, the first emergence of the adults of the 2nd generation developing on mummy almonds would occur ca. 950°D after the first eggs of the 2nd generation were laid. Data sets from 1981 and 1984 confirm the validity of this scenario.

3. In rare years, the 2nd flight occurs much later than the start of hullsplit. In this case, the timing of management practices based on a hullsplit initiation biofix would be premature, because the 2nd generation individuals would begin development on new-crop almonds much later than at hullsplit initiation. Determining the beginning of the 3rd flight in this case is very difficult to do with adequate precision, unless it can somehow be accurately determined when the eggs of the 2nd generation were first laid. A very rough prediction of the start of the 3rd flight can be made by accumulating 1550°D from the date of peak egg laying in the spring (1550°D = 950°D for early development of 1st generation on mummies, plus 600°D for early development of 2nd generation on new-crop nuts). Data sets from Kern Co. in 1983 support this forecast.

In order to accurately use this degree-day information, we make the following recommendations:

<u>Sprays</u>. At present we do not know how a spray application would affect the phenology of the navel orangeworm, although it would seem that it would delay population events. Since we do not know the effect of sprays, this degree-day information is not yet recommended for use in orchards which receive a hullsplit spray.

Egg Traps. As indicated in another section of this report, both the standard Pherocon IV egg traps as well as those painted black are able to detect the beginning of the 3rd flight, as confirmed by concurrent increases in blacklight trap catches. The traps painted black usually had higher numbers of eggs, which is more desirable, but the white traps also appeared to be adequate.

Traps should be baited with fresh almond presscake, and the bait should be changed every 2-3 weeks during the summer. Eggs on the traps should be counted twice a week during late spring and summer for better precision.

Interpretation of egg trap data after Nonpareil hullsplit initiation must take into account that egg trap catch is suppresssed at hullsplit initiation. As well, after harvest shake, egg trap catch rises abruptly because of lack of competition with the harvested almonds.

Temperature Records. Accurate maximum-minimum temperature records are crucial for precise degree-day calculations. A recently calibrated thermograph or a maximum-minimum thermometer (which is checked daily) is necessary. For best results these devices should be in the almond orchard of interest, although temperature records from a nearby orchard of similar age and cultural practice may be adequate. At present, we do not recommend the use of regional temperature records which do not come from an orchard source. Temperatures in an open field or fire station may be significantly different from those inside an almond orchard.

Degree-day accumulation for the navel orangeworm can be calculated from Table 2. The values in this table are calculated using double triangulation, and are based on a lower developmental threshold of 55°F, and an upper developmental threshold of 94°F, using a vertical cutoff. To use the table requires 2 look-ups for each day; one for the minimum to the maximum temperatures of the same day, the other for the maximum of that day to the minimum of the next day.

Hullsplit detection. Since soft-shelled almonds are infestable by NOW as soon as their hulls split, and since hullsplit first starts in treetops, determining the start of hullsplit in the treetops of Nonpareil almonds is critical to the prediction of the earliest time that 2nd generation emergence from new-crop almonds could occur. An almond is considered split if there is a visible opening of any size along the future of the hull, and this is determined without squeezing the hull (A navel orangeworm can only enter a nut via a naturally-occurring opening). To sample an orchard for the onset of hullsplit, arbitrarily choose 5-10 trees/100 acres, and select 15-20 nuts from the top SW corner of each tree. Do not choose any border trees, and disregard any hullsplit "blank" almonds sampled. Sample every 3-4 days until hullsplit of sound nuts is detected.

Using all of the preceding information, the following is our present recommendations for the use of degree-days coupled with egg trap data, to predict the beginning of adult emergence of the 2nd generation (3rd flight).

In orchards where successful sanitation has been achieved and early harvest of Nonpareils is to be practiced for navel orangeworm control, without a hullsplit spray, the onset of emergence of the third flight may be predicted, using °D accumulation, and confirmed using egg traps. The onset of this emergence, from the newly hullsplit almonds, should occur about 600-650°D from hullsplit initiation in the tops of the trees, and as calculated using Table 2. To confirm the start of the third flight, install egg traps about 400°D after hullsplit and check them twice a week. In an occasional year when the second flight begins well after hullsplit, the third flight will accordingly begin later, i.e. more than 650°D after hullsplit.

In orchards with a significant mummy load at hullsplit (more than one soft-shelled mummy per tree), a hullsplit spray should be applied. When the second flight begins more than 2 weeks before hullsplit, the third flight, developing from mummy nuts, should begin about 950°D after the start of the second flight. This will be after initiation of hullsplit and may well call for application of an additional spray. To determine when the second flight begins, install egg traps about June 1, check them twice a week and watch for an upsurge in oviposition. If the second flight begins after two weeks before hullsplit, which is usually the case, the start of the third flight is best determined solely by monitoring egg traps beginning about 400°D after initiation of hullsplit, as the effect of the hullsplit spray may influence the phenology of the 2nd generation, delaying issuance of the third flight from the crop. Among all of the 10 data sets examined, the beginning of the 3rd flight never occurred prior to 400°D after treetop hullsplit initiation, despite when the 2nd flight occurred. Therefore, the simplest, although less accurate, way to use this information is to place egg traps in the orchard 350-400°D after hullsplit initiation, and monitor them until the first substantial increase in egg trap catch occurs. This will probably signal the beginning of the 3rd flight.

Table 1. Accumulated degree-days for navel orangeworm development for several years on new-crop and mummy almond substrates.

Year	Almond substrate	No. individuals	Average[a] °D	Range °D
1981[b]	New Crop	207	763	580-1006
1982[b]	New Crop	236	769	594-1126
1982[b]	Mummies	217	1122	621-1626
1983 (Spring)	Mummies	614	1112	876-1400
1983 (Summer)	Mummies	635	1140	c
1984	Mummies	131	1116	893-1489

[a] Includes 100°D for egg development.

[b] Data of Seaman (1982 Annual Rpt.).

[c] Cannot be accurately estimated.

Table 2. DEGREE-DAY TABLE FOR NAVEL ORANGEWORM DEVELOPMENT ON ALMOND

DEGREE-DAYS ABOVE: LOWER THRESHOLD: 55.00 F UPPER THRESHOLD: 94.00 F DOUBLE TRIANGULAR
THREE-POINT METHOD: TWO LOOKUPS PER DAY VERTICAL CUTOFF

MINIMUM TEMPERATURES

MAX TEMPS	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90
40	0	0	0	0	0																									
42	0	0	0	0	0	0																								
44	0	0	0	0	0	0	0																							
46	0	0	0	0	0	0	0	0																						
48	0	0	0	0	0	0	0	0	0																					
50	0	0	0	0	0	0	0	0	0	0																				
52	0	0	0	0	0	0	0	0	0	0	0																			
54	0	0	0	0	0	0	0	0	0	0	0	0																		
56	0	0	0	0	0	0	0	0	0	0	0	0	1																	
58	0	0	0	0	0	0	0	0	0	0	0	1	1	2																
60	0	0	0	0	0	0	0	0	1	1	1	1	2	2	3															
62	0	0	0	1	1	1	1	1	1	1	1	2	2	3	3	4														
64	1	1	1	1	1	1	1	1	1	1	2	2	3	3	4	4	5													
66	1	1	1	1	1	1	1	2	2	2	2	3	3	4	4	5	5	6												
68	1	1	1	1	2	2	2	2	2	2	3	3	4	4	5	5	6	6	7											
70	1	2	2	2	2	2	2	2	3	3	3	4	4	5	5	6	6	7	7	8										
72	2	2	2	2	2	2	3	3	3	3	4	4	5	5	6	6	7	7	8	8	9									
74	2	2	2	3	3	3	3	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10								
76	3	3	3	3	3	3	3	4	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11							
78	3	3	3	3	3	4	4	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12						
80	3	3	4	4	4	4	4	5	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13					
82	4	4	4	4	4	5	5	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14				
84	4	4	4	5	5	5	5	6	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15			
86	4	5	5	5	5	5	6	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	16		
88	5	5	5	5	6	6	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	
90	5	5	6	6	6	6	7	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	17	18
92	6	6	6	6	7	7	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	17	18	18
94	6	6	7	7	7	7	8	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	17	18	18	19
96	6	6	6	7	7	7	7	8	8	8	9	9	10	10	10	11	11	12	12	12	13	13	14	14	14	14	14	14	14	12
98	6	6	6	6	7	7	7	7	8	8	8	9	9	9	10	10	11	11	11	12	12	12	12	12	12	12	12	12	11	9
100	6	6	6	6	6	7	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	11	11	11	11	11	11	10	9	7
102	5	6	6	6	6	6	7	7	7	7	8	8	8	9	9	9	9	10	10	10	10	10	10	10	10	10	9	9	8	6
104	5	5	6	6	6	6	6	7	7	7	7	8	8	8	9	9	9	9	9	10	10	10	10	10	9	9	9	8	7	5
106	5	5	5	6	6	6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	9	9	9	9	9	8	8	7	6	5
108	5	5	5	5	6	6	6	6	6	7	7	7	7	8	8	8	8	8	8	9	9	9	8	8	8	8	7	6	5	4
110	5	5	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8	8	8	8	8	8	8	8	7	7	7	6	5	4
112	5	5	5	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8	8	8	8	8	8	7	7	7	6	5	5	3
114	5	5	5	5	5	5	5	6	6	6	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	6	6	5	4	3
116	5	5	5	5	5	5	5	5	6	6	6	6	6	7	7	7	7	7	7	7	7	7	7	7	6	6	5	5	4	3
118	4	5	5	5	5	5	5	5	5	6	6	6	6	6	6	7	7	7	7	7	7	7	6	6	6	6	5	4	4	3
120	4	4	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	7	6	6	6	6	6	6	5	5	4	3	2

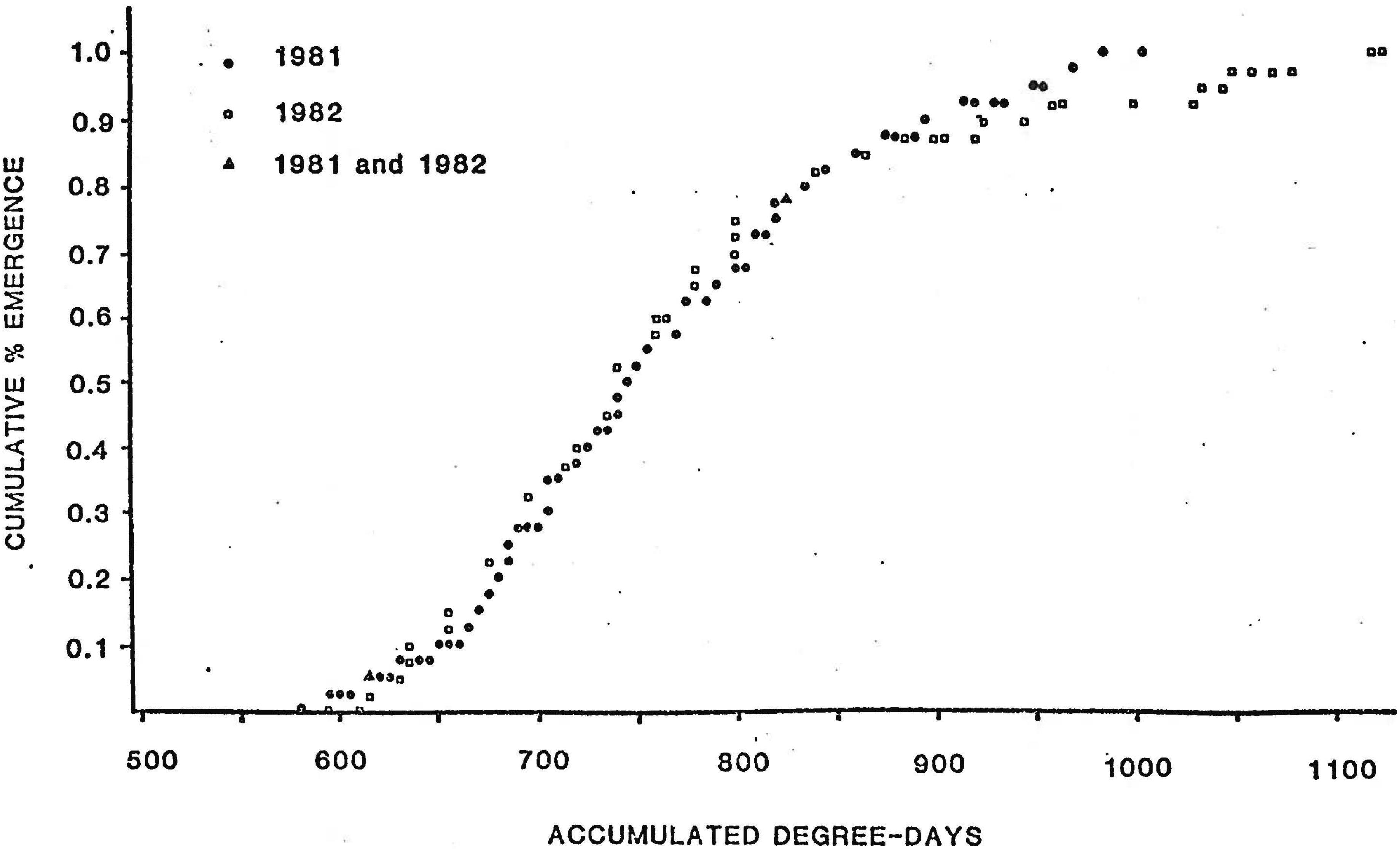

FIG. 1. Accumulated degree-days vs. cumulative % adult navel orangeworm emergence of individuals developing on new-crop Nonpareil almonds in 1981 and 1982. Data from Seaman (1983).

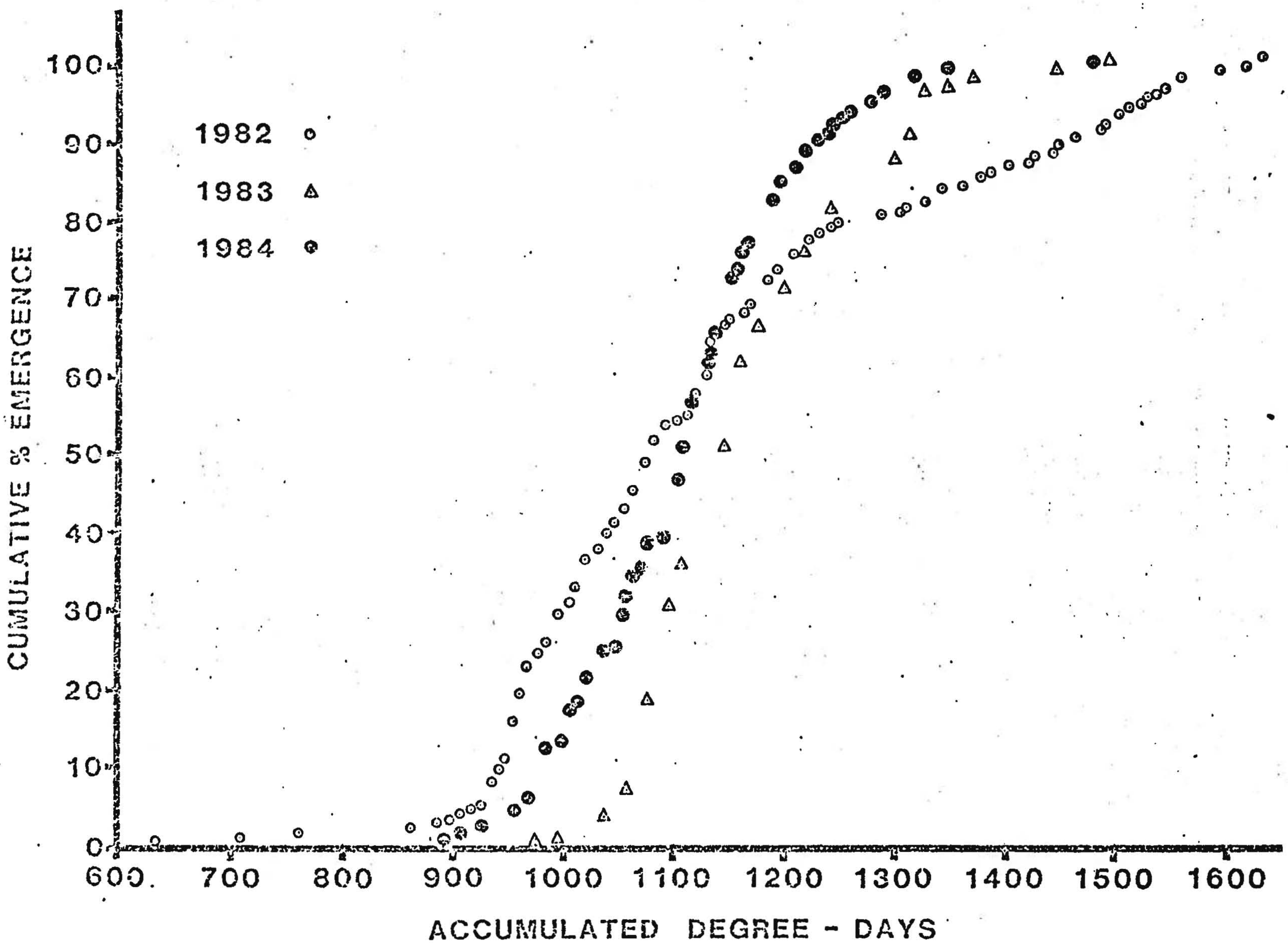

FIG. 2. Accumulated degree-days vs. cumulative % adult navel orangeworm emergence of individuals developing on mummy Nonpareil almonds in 1982, 1983, and 1984. 1982 data from Seaman (1982 Annual Report).

The Use of Egg Traps in Monitoring Post-Hullsplit Navel Orangeworm Activity

J. P. Sanderson and M. M. Barnes

Egg traps, developed by Dr. R. E. Rice and improved by Dr. R. A. Van Steenwyk and W. W. Barnett, are presently the best method of monitoring navel orangeworm activity, especially activity prior to hullsplit of the earliest-maturing almond variety in an orchard. After hullsplit initiation, however, trap catches usually decline, although the navel orangeworm population is still actively laying eggs. The reason for the decline in trap catch is thought to be competitiion of attractiveness between the egg traps and the abundance of newly-hullsplit almonds.

Recent improvements in bait and color of egg traps by Rice, Van Steenwyk, and Barnett have been shown to make traps more attractive to navel orangeworm females. Because we are interested in using trends in egg trap catch to confirm degree-day predictions of the start of the 3rd flight, we compared the relative ability of black vs. white egg traps to monitor post-hullsplit navel orangeworm activity, using blacklight trap catches as controls.

Materials and Methods

Portions of 3 almond orchards in Kern Co., Calif., were selected for the study. One orchard was located ca. 3 mi. NE of Arvin, and contained 14-year-old Nonpareil, NePlus, and Mission variety trees. It was flood-irrigated, and did not undergo winter sanitation. The other 2 orchards were located near Shafter, and were comprised of 11-year-old flood-irrigated Nonpareil, Mission, and Merced variety trees. One of the latter orchards

(R88) was cleaned of mummies in winter (less than 1/2 nut per tree in May), the other (R64) contained a 7-acre experimental plot (in which our study was conducted) which was not cleaned. A Guthion spray was applied to the Arvin orchard on 6/29/84; the other 2 orchard plots were unsprayed.

The navel orangeworm population in all 3 orchards was tracked from 2/21/84 to 9/26/84, using 8-10 standard, white Pherocon IV egg traps in each orchard. Traps were filled half-full with almond presscake. Traps were checked and the bait changed once a week until the end of June. Beginning 6/26/84, 8 to 10 egg traps which had been painted with Ace Spray Enamel-104 Gloss Black were also installed in the orchards. All traps were hung in the N side of trees, and were spaced 1 trap in every 5th tree in every 5 or 10 rows, depending on the size of the experimental plot. The position of the black and white traps in each plot was re-randomized weekly. Eggs were counted and removed from the traps every 3-4 days, and bait was changed weekly.

Ultra-violet (U.V.) traps with either 4 or 8 watt bulbs were placed in the orchards in the beginning of July. Navel orangeworm moths caught in these traps were counted daily until the end of August.

Results and Discussion

The U.V. trap catch curves in Figs. 1-3 indicate that the beginning of the 3rd flight occurred around 7/24/84 in all 3 orchards. Both the black and white egg trap curves began to increase at roughly the same time, indicating that they were sufficiently attractive by this date to indicate fairly accurately the start of the 3rd flight. The black traps had at least as many, and usually more eggs than the white traps throughout the experiment. However, both white and black traps appeared to adequately detect the start of the 3rd flight in these 3 orchards.

Similar data collected in 2 Kern Co. orchards in 1983 using white egg traps, compared with U.V. trap catches, also indicated that egg traps were adequate in detecting the start of the 3rd flight.

Egg traps can therefore be used to fairly accurately detect the start of the oviposition of the 3rd flight. There will be some delay in detection, however, because the traps are usually checked every 3-4 days.

Interpretation of egg trap data after trees are shaken is questionable. The navel orangeworm only lays eggs on nuts or egg traps in the trees. The removal of nuts from trees to the ground may result in a sudden increase in eggs laid on the egg traps because fewer oviposition sites would then be available. Therefore, the resulting egg trap catch data would indicate an erroneous population increase.

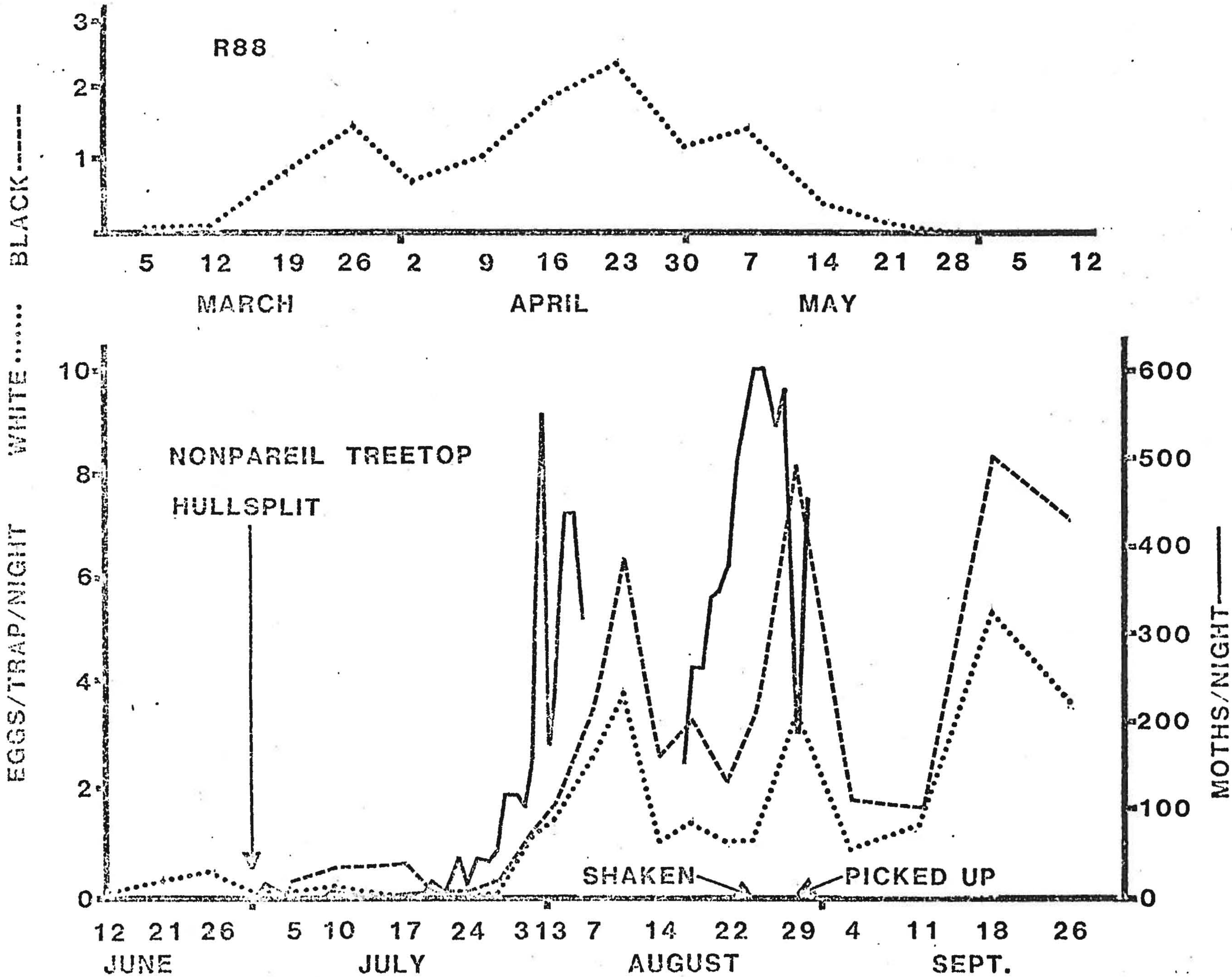

FIG. 1. Ability of both black and white egg traps to monitor post-hullsplit NOW activity, compared to U.V. light traps.

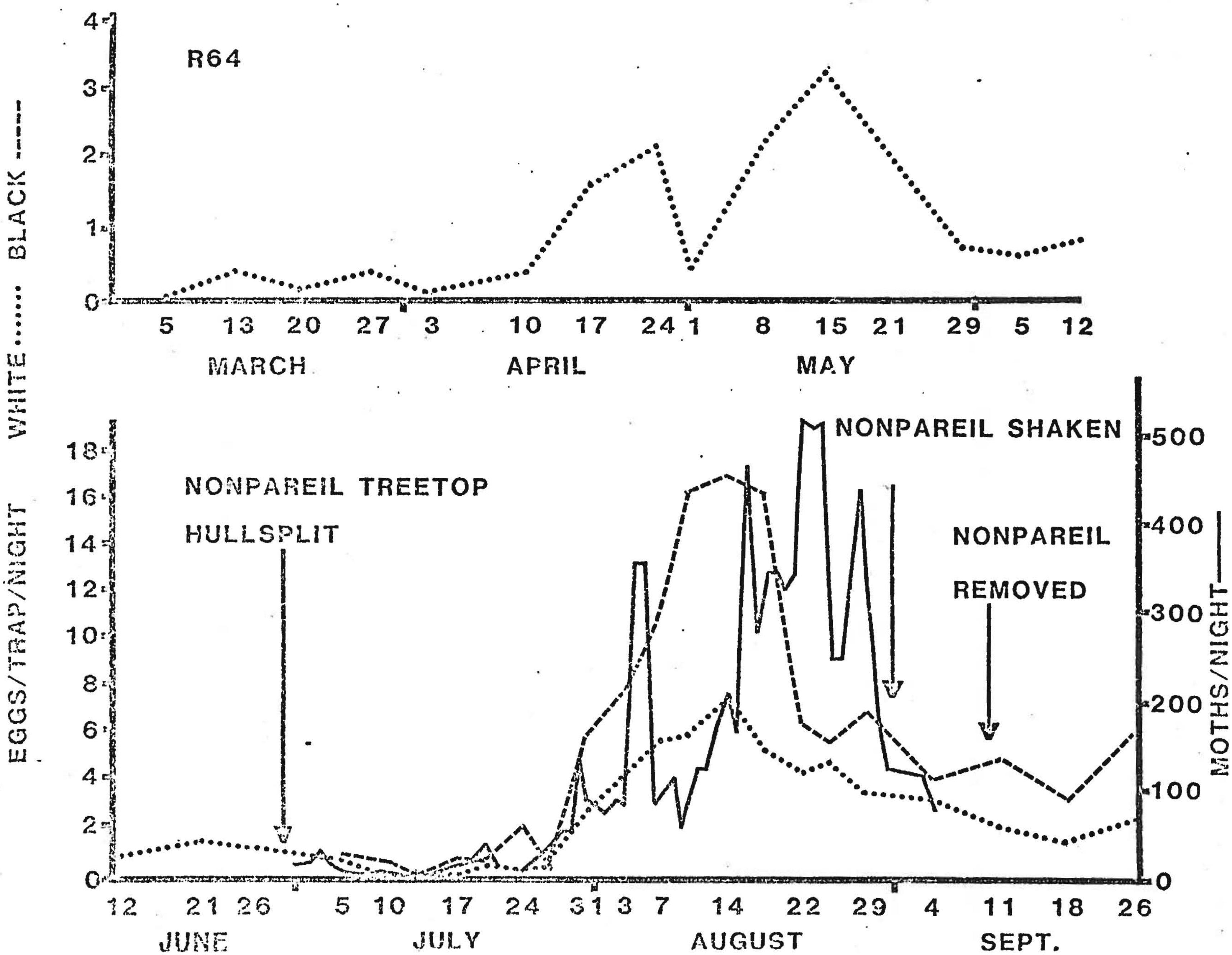

FIG 2. Ability of both black and white egg traps to monitor post-hullsplit NOW activity, compared to U.V. light traps.

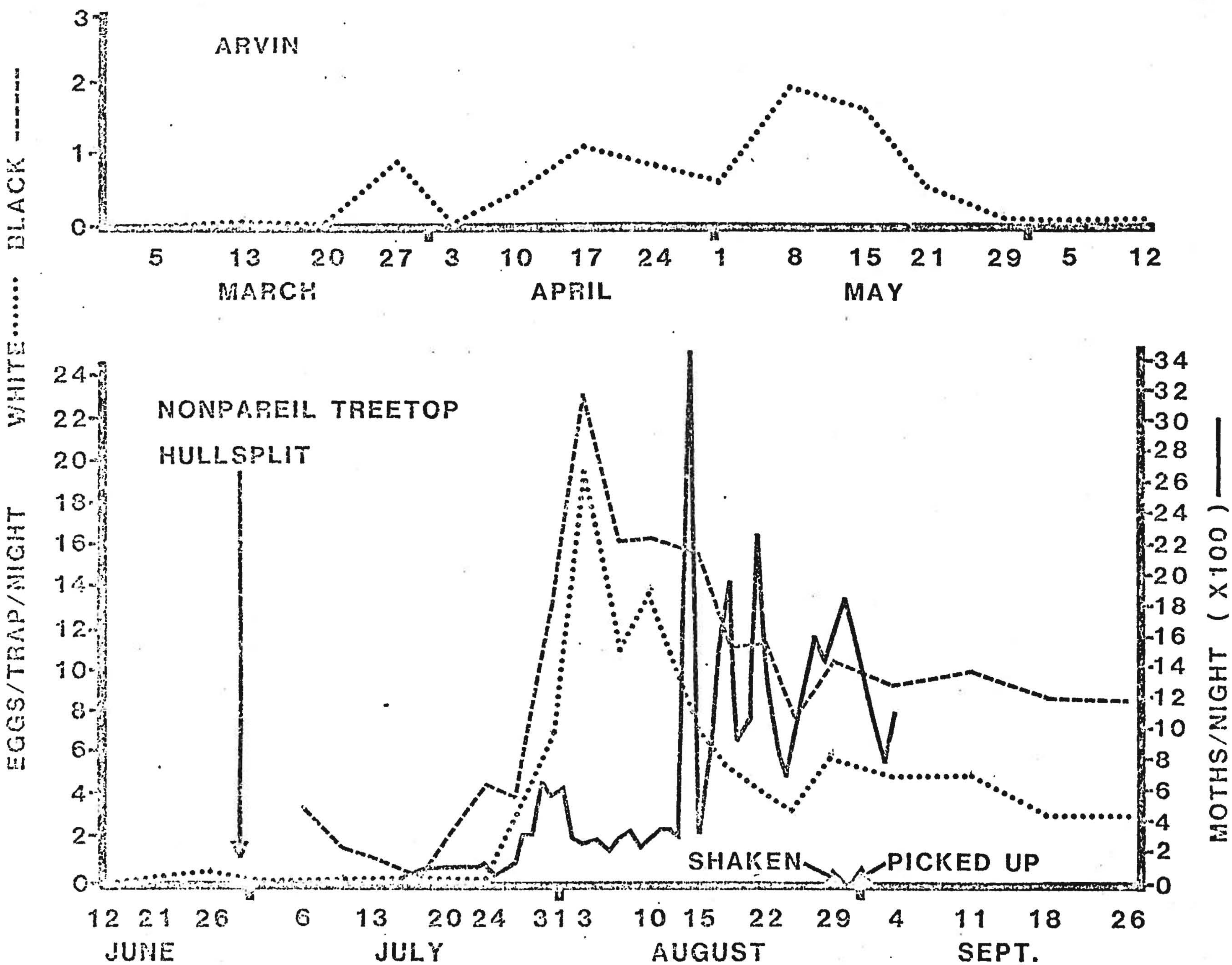

FIG. 3. Ability of both black and white egg traps to monitor post-hullsplit NOW activity, compared to U.V. light traps.

Number of Larval Instars of the Navel Orangeworm on Mummy and New-Crop Almonds

J. P. Sanderson and M. M. Barnes

Previous workers have documented that the navel orangeworm can go through extra instars under suboptimal conditions. In an effort to determine the thermal summation of each instar on both mummy and new-crop almonds, it was discovered that apparently only 5 larval instars were necessary for development on new-crop almonds in the field, compared to the well-known requirement of 6 larval instars on mummy almonds.

Materials and Methods

Two newly-hatched first-instar larvae were placed per nut either in caged newly-hullsplit Nonpareil almonds still attached to mature trees in Kern Co. orchards in 1983 and 1984, or in uninfested Nonpareil mummy almonds collected from Kern Co. trees in December, 1983 and caged in the canopies of 5-year-old almond trees in the UCR Biological Control orchard in March, 1984. All larvae used were produced by wild female moths, except for the 1983 new-crop study in which larvae from a 7th generation lab culture were used.

Samples of these artificially infested nuts were taken from the trees periodically between 40 and 800°D after ionoculation. Thirty-one, 17, and 42 samples were taken from mummies in 1984, new-crop nuts in 1983, and new-crop nuts in 1984, respectively. Each sample consisted of at least 5 nuts.

The nuts were cracked out in the laboratory, and the recovered larvae were preserved in 70% ethyl alcohol until their head capsule widths could be measured. The width of each head capsule was measured with a dissecting microscope fitted with a calibrated ocular micrometer. Increased magnification was used to measure the smaller larvae.

A frequency distribution (histogram) of head capsule widths was then constructed for each of the 3 studies. The number of larval instars required for development during each study corresponds to the number of peaks which occur in each histogram.

Results and Discussion

The histograms of head capsule widths from 1984 mummies, 1983 new-crop nuts, and 1984 new-crop nuts are shown in Figs. 1-3, respectively. Previous studies of mummy almond samples have shown histograms with 6 peaks, indicating the requirement for 6 larval instars for development on mummy almonds. Fig. 1 also displays 6 peaks, and confirms that 6 larval instars were required in this study on mummies. However, only 5 peaks are shown in the histograms constructed from measurements of larvae developing on new-crop almonds in both 1983 and 1984. Therefore, these data indicate that the navel orangeworms passed through only 5 larval instars during development on new-crop almonds. A comparison of Fig. 1 with Figs. 2 or 3 indicates that it is the 4th instar which is required on mummy nuts and not on new-crop nuts. That is, a peak can be observed in Fig. 1 between 0.66 and 0.72 mm that is absent in both Figs. 2 and 3. All other peaks occur consistently at similar measurements in all 3 histograms. A slight discrepancy in the location of the 5th peak of Figs. 2 and 3 could be the result of heavy parasitism by Goniozus legneri which was observed in the larger larvae recovered from the 1984 new-crop almonds. The parasites may have somehow prevented many of these larvae from reaching the apparently normal size for the final instar, which can be observed in Figs. 1 and 2.

This information correlates well with the degree-day requirements for total development on the 2 substrates. An average of many more degree-days is required for total development on mummy almonds (ca. 1125°D) compared to that for newly-hullsplit almonds (ca. 766°D). The extra instar needed for development on mummies at least in part accounts for the additional thermal-unit requirement.

Wade (1961) showed that, at 95% relative humidity, most navel orangeworms, developing on almonds, passed through 5 instars, whereas at both 85 and 75% RH, most went through 6 instars. At 55% RH, 6 or 7 instars were required for development. The greater moisture content of newly-hullsplit almonds, compared to that of mummies, may in part explain why fewer instars occurred on new-crop nuts than on mummies. Relative humidity inside a newly-hullsplit almond kernel could well be near 100%.

However, work published by R. K. Curtis and M. M. Barnes in 1977 indicated that head capsule measurements from navel orangeworms collected from new-crop almonds in 1975 could be sorted into 6 discrete classes representing 6 instars. The reason for the discrepancy between the present work and that of Curtis and Barnes (1977) is not known.

The data regarding the determination of the thermal summation of each instar on the 2 substrates are still being analyzed.

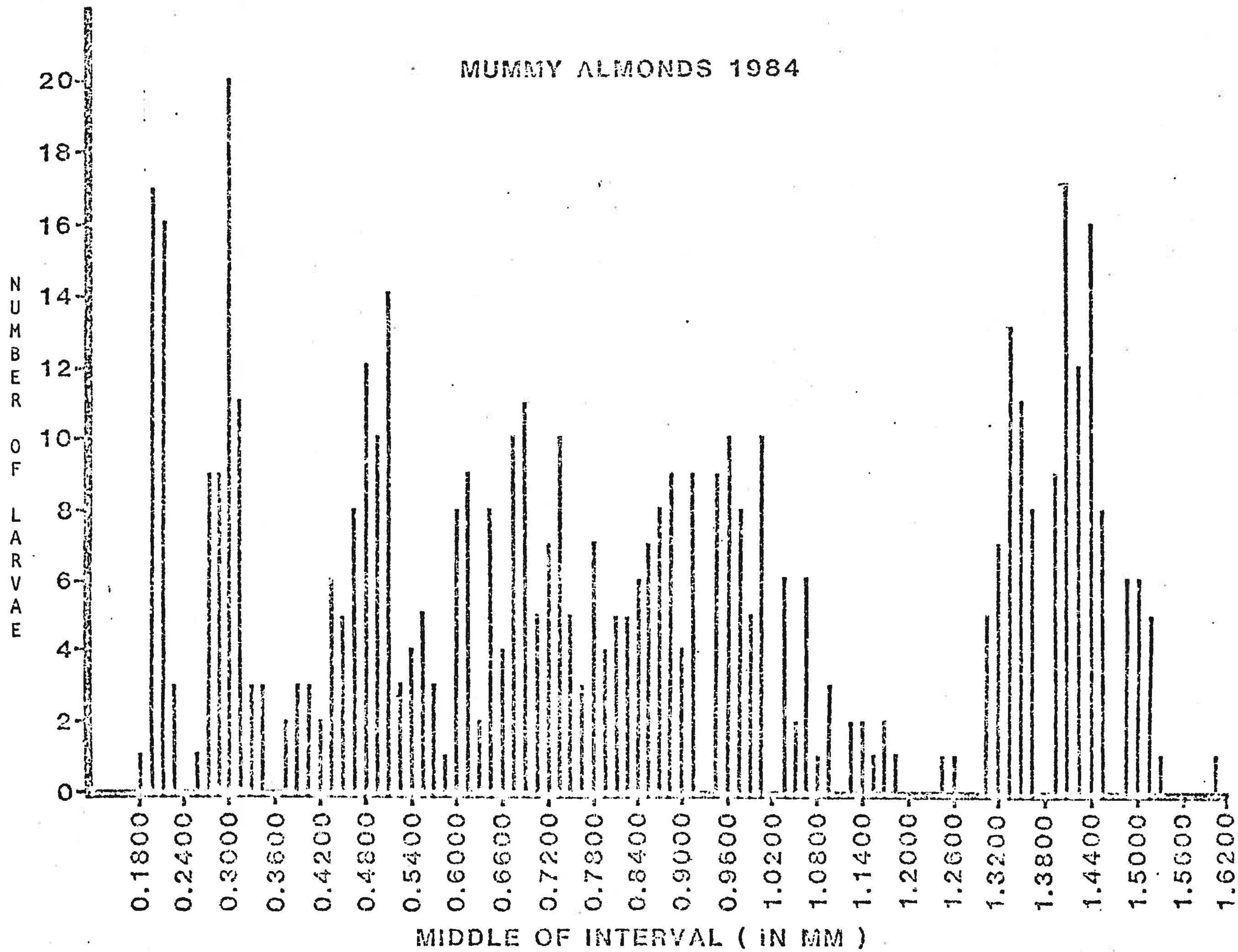

FIG. 1. Histogram of head capsule widths of navel orangeworm larvae taken from mummy almonds in 1984.

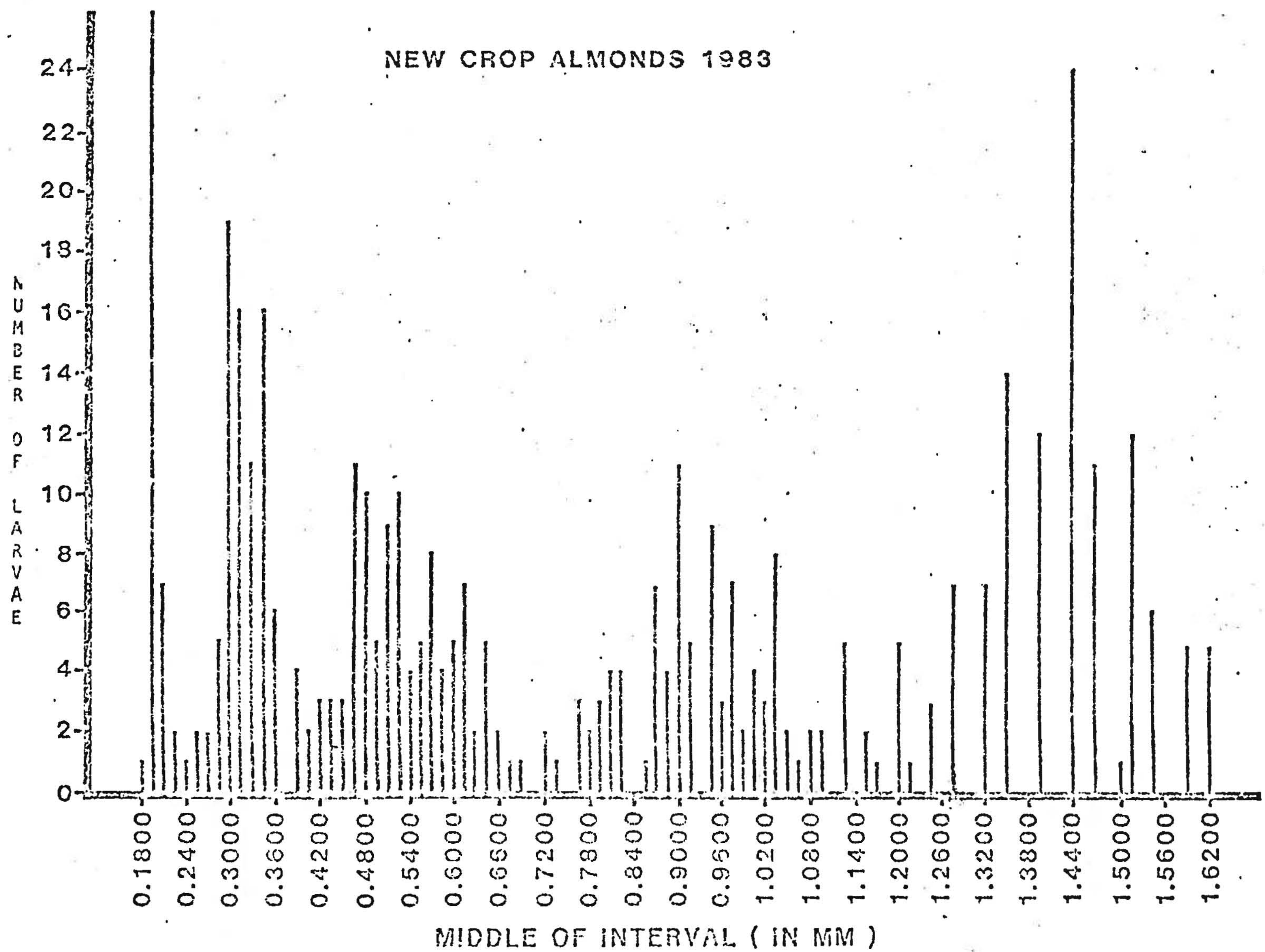

FIG. 2. Histogram of head capsule widths of navel orangeworm larvae taken from new crop almonds in 1983.

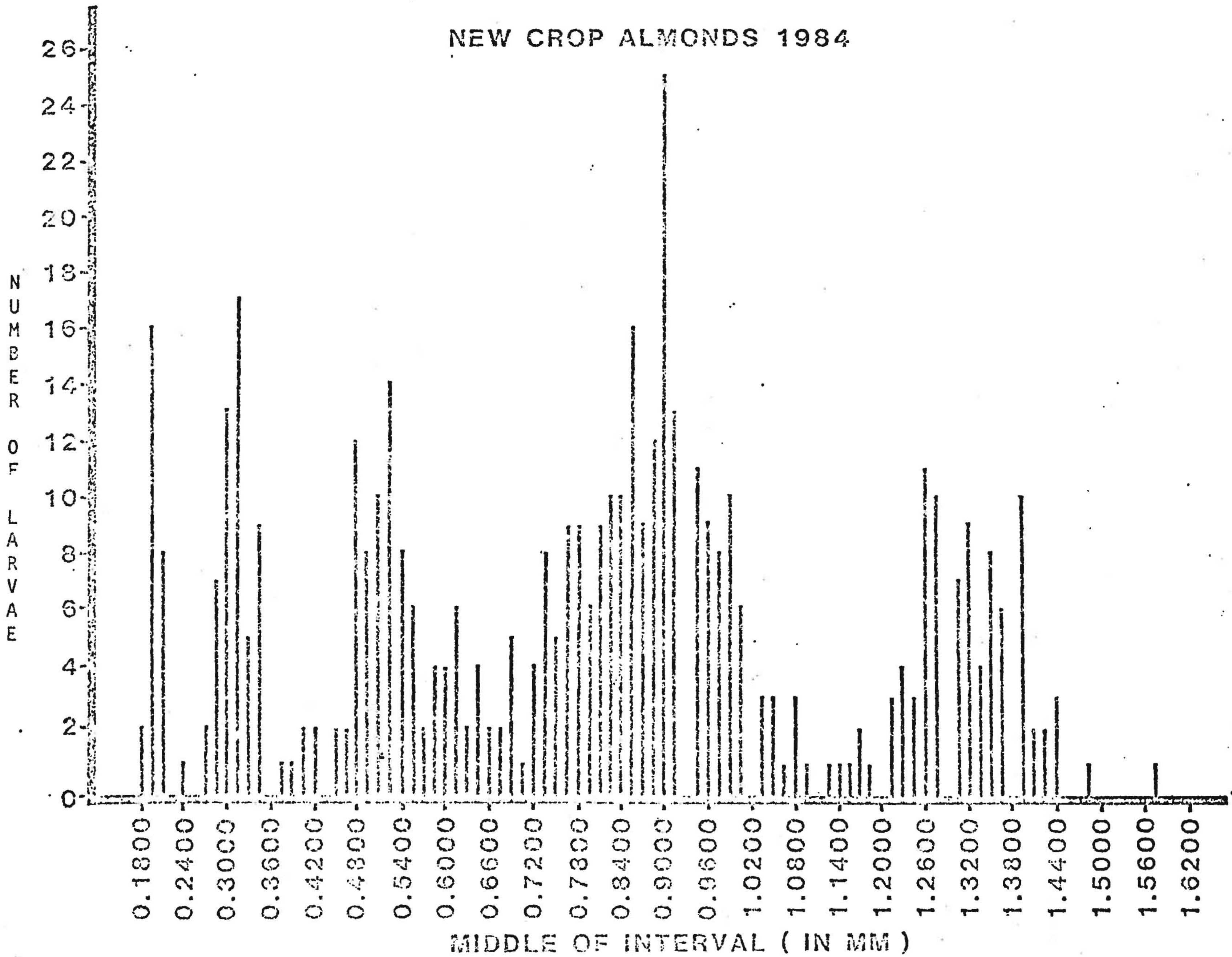

FIG. 3. Histogram of head capsule widths of navel orangeworm larvae taken from new crop almonds in 1984.

The Impact of Water Stress on Potted Almond Trees on Oviposition Rates of the Pacific Spider Mite

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

It is a widely held belief that spider mite populations rapidly increase on water stressed almond trees during the summer months. In field observations, tracking mite populations on trees under differential water stress, records suggested that egg deposition was occasionally higher on water stressed foliage. This required more careful examination. Therefore, a greenhouse study was conducted to determine if severe or intermediate water stress conditions would affect oviposition rates of the Pacific spider mite, *Tetranychus pacificus*, compared to a non-water-stressed control.

Materials and Methods

Fifteen 'Mission' almond trees were selected from a population of 40 trees, which were approximately one year of age, to be used in the water stress trial. The trees were grown in 12-gallon containers and maintained on a regular water and fertilizer schedule.

The severe and intermediate water stress conditions were based on the permanent wilting point. The permanent wilting point occurs when the leaves remain in a state of continuous wilt. If the tree continues to be deprived of water over a long enough period of time, cellular breakdown and leaf abscission will result.

To establish the permanent wilting point, a preliminary experiment was performed. Twelve trees were initially watered to excess and weighed to establish weight (container, soil, tree) at 100% field capacity. Field capacity is defined as the point at which the soil is thoroughly saturated and cannot hold additional water. After this was accomplished, the trees were deprived of water until they reached a state of continuous wilt for 24 hours. At that time, the containers were weighed and the results averaged to determine the percent of field capacity at which permanent wilting occurred.

The watering schedule of the three treatments was as follows: the control trees were given 8 liters of water every one to two days; the intermediately water stressed trees were given 6 liters of water when they became wilted; and the severely water stressed trees were given 750 ml of water every two days. The treatments consisted of 5 single-tree replicates.

Eight newly emerged and mated female spider mites were placed one to a leaf on each of the 15 trees. An arena, constructed from masking tape, was used to confine a single female mite to an area of 1 $in.^2$ on the upper surface of the leaf. Once the mites were in place they were checked daily to record the number of eggs produced by each female. the eggs were removed from the arena after being counted. This procedure was followed throughout the life of the mite.

Results and Discussion

The permanent wilting point of the water stressed almond trees occurred when the total weight was approximately 20% of the weight at field capacity. The trends in the water status of the three treatments are presented in Fig. 1. The weight of the controls never fell below 60% of the field capacity, and consequently the leaves of those trees were never in a wilted state. On the other hand, the leaves of the severely stressed trees were in a state of continuous wilt. Their weight was near the 20% level throughout the trial. The leaves of the intermediately stressed trees wilted when the tree's weight

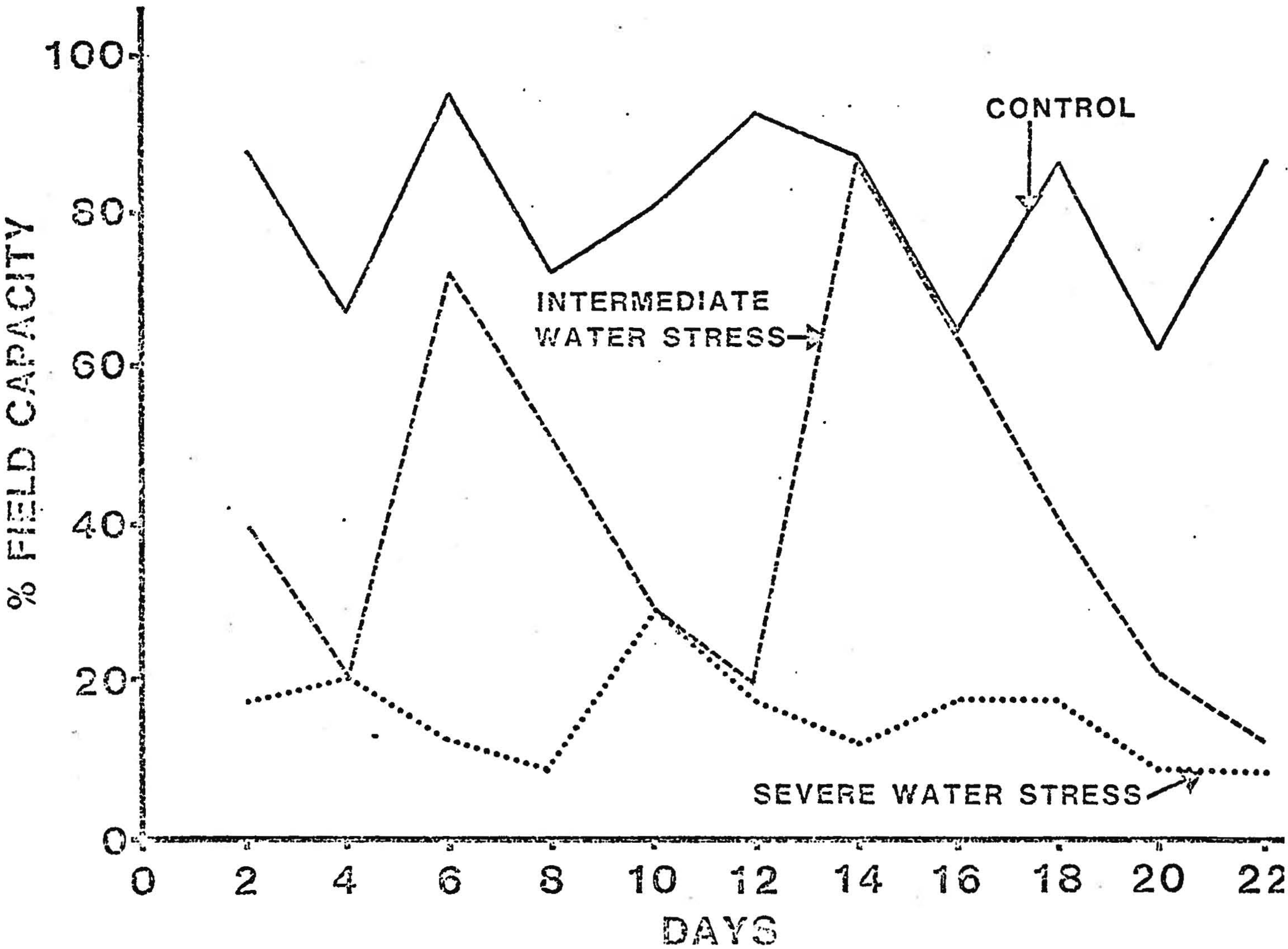

FIG. 1. Water status of soil in which trees were maintained.

dropped to 20% field capacity; however, the condition was reversed shortly thereafter through watering.

The mean daily oviposition rate of the females for all three treatments was plotted in Fig. 2. No striking trends are evident; however, in terms of total egg production, the females on the control trees laid an average of 172 eggs compared to 165 and 140 eggs on the intermediately and severely stressed trees, respectively. The overall period of egg production lasted 25 days on the control trees, 19 days on the intermediately stressed trees, and 17 days on the severely stressed trees.

These data do not support the hypothesis that oviposition by spider mites is greater on water stressed almond foliage -- especially on those trees which are continuously and severely water stressed.

It is conceivable that a shift in the sex ratio favoring the production of female offspring on water stressed trees could lead to greater spider mite densities.

Afternoon temperature readings were taken on leaves of severely water stressed trees and non-water stressed trees (control). The results demonstrated that temperatures of the stressed leaves were very close to ambient conditions while temperatures of the control leaves were 8 to 9°F lower. Higher leaf temperatures on water stressed trees could decrease the generation time which would lead to a more rapid buildup of a spider mite population.

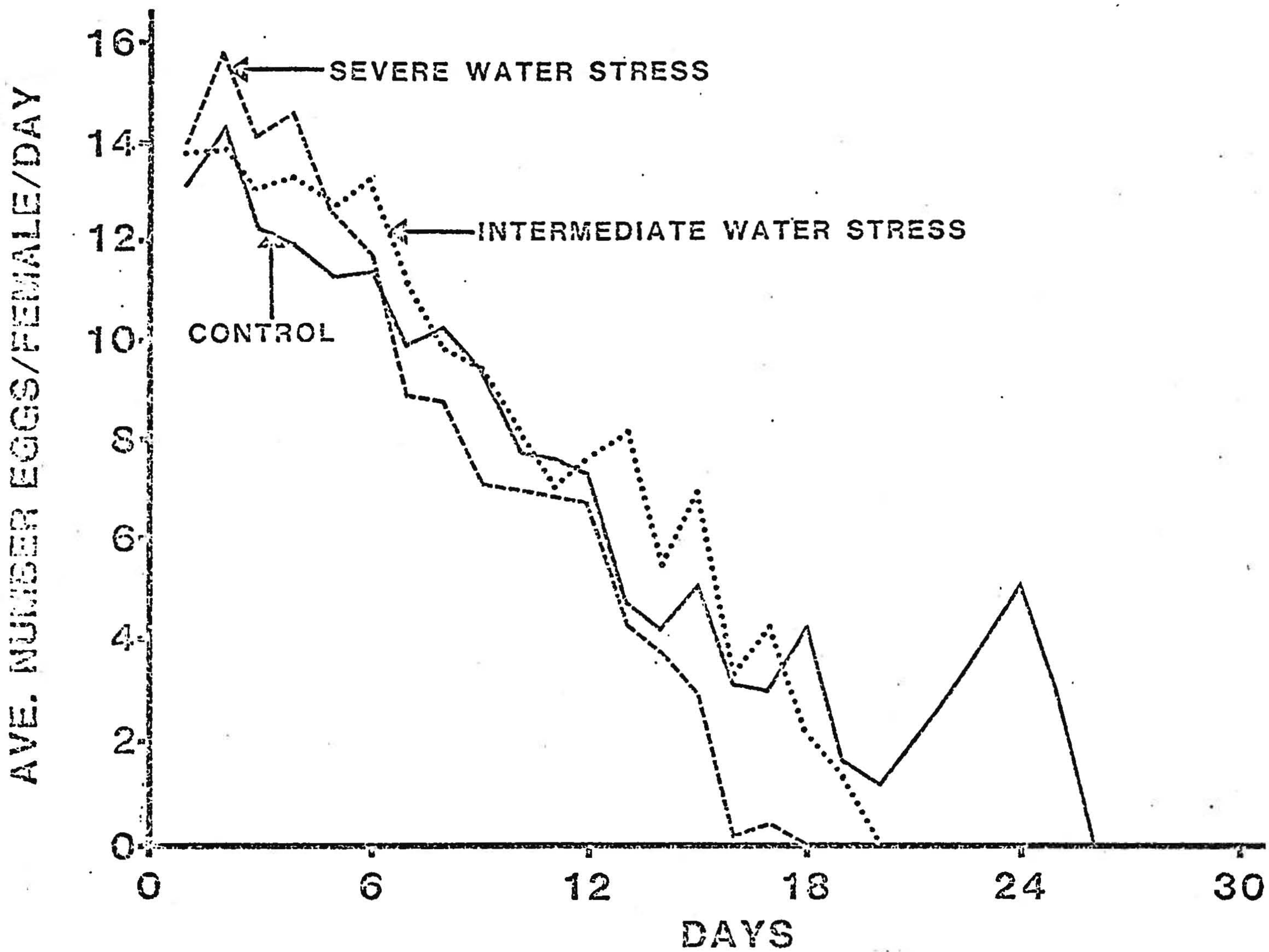

FIG. 2. Mean daily oviposition rates by Pacific mite.

1984 Acaricide Efficacy Trial

D. H. Oi, M. M. Barnes, and E. F. Laird

Field evaluation of seven compounds and a water check on spider mite and spider mite predator populations on almond trees was conducted from July 2 to August 14, 1984, in the southern San Joaquin Valley. FMC-54800 2EC and Larvin 80DF, each applied at two concentrations, were compared with a water check and a Plictran 50W standard.

Materials and Methods

The experimental plot was located approximately 1/2 mile north of Kimberlina Rd. and 3 miles east of Hwy. 99, which was in Ranch 88 of the Superior Farming Company, in Kern County, Calif. Treatments were laid out in a randomized complete block design with eight single-tree replicates. The trees were flood irrigated, third leaf, Carmel variety almonds.

Materials were applied on July 3 with a high pressure handgun (#8 disc) at an application rate of 800 gal/acre. Each tree was sprayed until runoff (approx. 5 gal/tree). Treatments are listed in Tables 1 and 2.

To assess spider mite and spider mite predator populations, five leaves were randomly removed, between the heights of 4 and 7 ft, from the four directional quadrants of each tree. Hence a total of 20 leaves/tree was examined with a dissecting microscope to obtain counts of all spider mite stages, except eggs, and of the active stages of spider mite predators. Sampling dates were at weekly intervals for a month, while the last sample was taken six weeks after spraying. Visual observations for phytotoxicity were made on each sampling date.

Spider mite populations from the pretreatment samples consisted primarily of the Pacific spider mite, *Tetranychus pacificus.* The European red mite, *Panonychus ulmi*, was also present but in substantially less numbers. A postspray sample taken on July 31 revealed that mite populations consisted almost exclusively of the Pacific spider mite. The spider mite predators that were observed included the sixspotted thrips, *Scolothrips sexmaculatus*, a coccinellid beetle, *Stethorus* sp., the phytoseiid mites, *Metaseiulus occidentalis* and *Euseius tularensis*, a green lacewing, *Chrysopa* sp., and a cecidomyiid larvae, probably *Feltiella* sp.

A two-way analysis of variance and Duncan's new multiple range test were used to evaluate the treatment effects on mean spider mite and predator populations per leaf for each sampling date. Raw data was transformed using a logarithmic transformation ($\log_{10}(x+1)$). A 5% significance level was used for all analyses.

Results and Discussion

Pretreatment populations of spider mites and predators were statistically equivalent across all treatments with averages of 15.9 mites/leaf and 0.4 predators/leaf. One week after spraying, the spider mite populations were reduced in all treatments except in the two Larvin treatments. Predator populations were reduced likewise with the exception of the water check in addition to the Larvin treatments. Subsequently the Larvin and water treatments exhibited a general trend of increasing predator populations and a concomitant decrease in spider mite populations. By the third week, the three treatments had very low spider mite and predator populations which continued through the end of the trial (Tables 1 and 2). This indicated that the Larvin applications did not have a detrimental effect on the spider mite predators.

Among the FMC-54800 treatments, spider mite populations were reduced the first week after spraying. However, the treatments applied with the lower concentration (0.075 lb ai/acre) had the same reduction as the water treatment, in contrast to the higher concentration (0.15 lb ai/acre) which showed a significantly greater reduction. In the subsequent weeks there was a rapid buildup of spider mite densities in both treatments, while predator densities generally remained low. Treatments with the lower FMC concentration showed a quicker and greater increase in predators than the treatments with the higher concentration. Eventually treatments with the lower concentration had lower spider mite densities and higher predator densities than treatments with the higher FMC concentration (Tables 1 and 2). Spider mite resurgence in the FMC treatments was evident by the second week after spraying. The Plictran treatment had the lowest postspray densities of both spider mites and their predators throughout the trial. No evidence of phytotoxicity was observed from any of the treatments.

Among the spider mite predators, the sixspotted thrips was the dominant species, comprising 74% of the predators in the pretreatment samples, and 86% and 74% for the postspray samples of the Larvin and the FMC treatments, respectively. Observations of surrounding trees revealed the presence of thrips, and these trees probably served as a source for thrips immigration into the experimental plot. Predator mite densities were practically nil throughout the trial.

None of the compounds were as effective as the Plictran standard in initially reducing spider mite populations. However, the Larvin treatments, with their minimal effect on predators, had similar spider mite densities to the standard, three weeks after spray application.

Table 1. Mean[a] number of spider mites (all stages except eggs) per leaf, Carmel almonds, Kern County, Calif. 1984.

Material	Rate (lb ai/acre)[b]	Sample date: 7/2 Pretreat	7/10 1 week	7/17 2 week	7/24 3 week	7/31 4 week	8/14 6 week
FMC 54800 2EC	0.075	19.53 a	7.36 b	28.36 b	23.51 a	23.33 a	50.72 b
FMC 54800 2EC	0.15	16.09 a	1.43 c	9.38 a	13.76 a	34.48 a	147.88 a
Larvin 80DF	1.0	16.75 a	24.34 a	10.44 a	0.15 b	0.07 bc	0.82 c
Larvin 80DF	1.5	13.51 a	29.19 a	7.41 a	0.22 b	0.16 b	1.10 c
Plictran 50W	0.75	13.34 a	0.09 d	0.20 c	0.11 b	0.02 c	1.31 c
Water	-	16.21 a	9.76 b	1.46 b	0.06 b	0.04 bc	0.53 c

a Means based on 8 single tree replicates of 20 leaves per tree; means in the same column followed by the same letter are not significantly different at the 5% level using Duncan's NMRT. Duncan's NMRT was performed on data transformed using $\log_{10}(X + 1)$.

b Applied at 800 gal/acre by high pressure handgun.

Table 2. Mean[a] number of active stages of spider mite predators[b] per leaf, Carmel almonds, Kern County, Calif. 1984.

Material	Rate (lb ai/acre)[c]	7/2 Pretreat	7/10 1 week	7/17 2 week	7/24 3 week	7/31 4 week	8/14 6 week
		Sample date					
FMC 54800 2EC	0.075	0.61 a	0.01 c	0.11 c	0.16 a	0.56 a	0.47 a
FMC 54800 2EC	0.15	0.47 a	0.01 c	0.02 c	0.03 b	0.23 b	0.16 b
Larvin 80DF	1.0	0.29 a	0.21 b	0.66 a	0.03 b	0.02 c	0.01 c
Larvin 80DF	1.5	0.34 a	0.47 a	0.77 a	0.04 b	0.03 c	0.00 c
Plictran 50W	0.75	0.51 a	0.01 c	0.00 c	0.00 b	0.01 c	0.01 c
Water	-	0.42 a	0.34 b	0.39 b	0.04 b	0.02 c	0.01 c

a Means based on 8 single tree replicates of 20 leaves per tree; means in the same column followed by the same letter are not significantly different at the 5% level using Duncan's NMRT. Duncan's NMRT was performed on data transformed using $\log_{10}(X + 1)$.

b Predominant predator species was the sixspotted thrips, Scolothrips sexmaculatus, comprising 74% and 82% of the predators in the pretreatment and postspray samples, respectively.

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