Project Number 76-E3

76-E3

Annual Report to Almond Board of California

on

Investigations on control of the navel orangeworm on almonds - 1976

M. M. Barnes

Department of Entomology

University of California at Riverside

Investigations on control of the navel orangeworm on almonds - 1976

M. M. Barnes
Department of Entomology
University of California, Riverside 92502

Insecticides; moth dispersal; oviposition behavior; mites

INSECTICIDE STUDIES.--This major part of our research program included comparison of 1) Guthion and Sevin for early season suppression of navel orangeworm in large plots, together with an examination of the value of including a miticide in early season, 2) a combination of early season plus hullcrack applications, 3) trial of aircraft applications of TEPP in the post-hullcrack period, and 4) the search for more effective insecticides.

Methods.--A 130-acre orchard (near the Kern-Tulare County line) of Roberts Farms Inc. was mapped to show distribution of sticktights. It was then divided into blocks of approximately 17 acres each for treatments and two check (unsprayed) areas of 8 acres each (see Fig. 1). Also included was a 5-row segment used for replicated single tree plots, comparing new materials and providing a third set of check data. The orchard layout required a low-profile sprayer and the larger plots were treated with a Bean speed sprayer using 375 gallons per acre at 3 mph. Aircraft treatment was at 10 gal/acre and was applied toward dusk, aiming at a period of moth activity. The single tree plots were replicated 10 times and were sprayed by handgun to full coverage, which required 10 gal/tree (1000 gal/acre).

Mite populations were measured by a rating system described later. At harvest, nut samples were taken as follows: 30 Nonpareil trees were

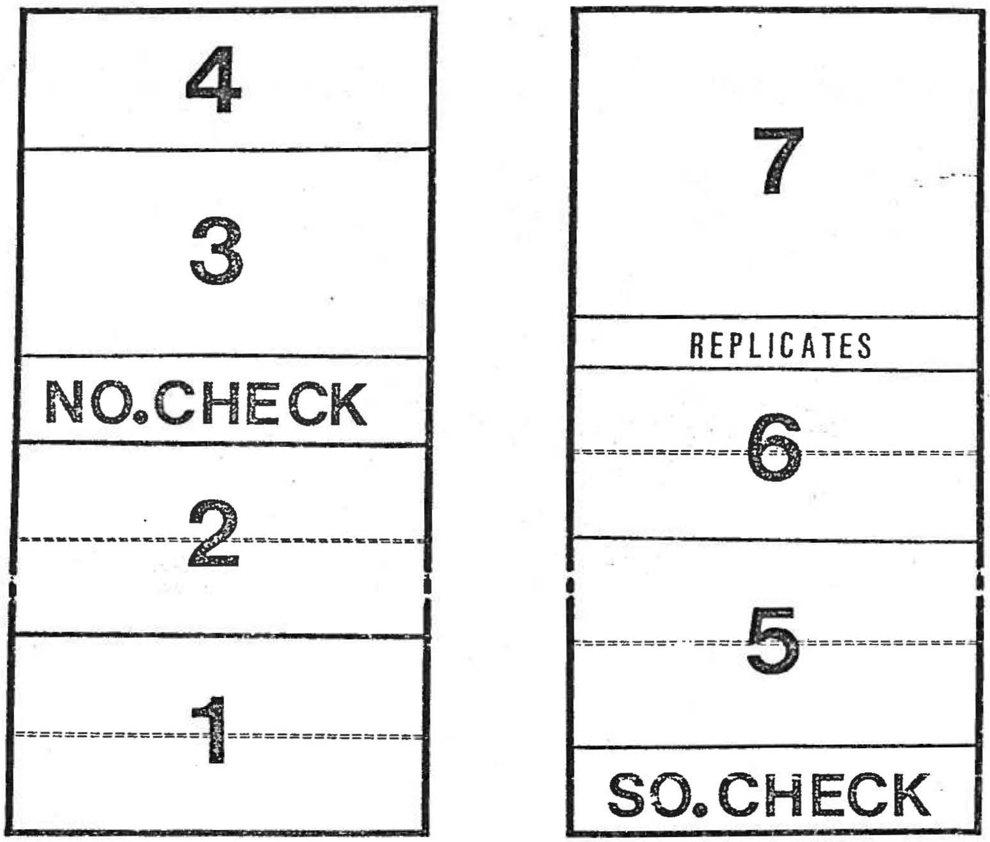


Figure 1. Plot layout in large block comparison of programs for navel orangeworm and two-spotted mite control, Richgrove, Calif., 1976.

knocked in the center area of each large plot and check plot. About 100 nuts per tree were gathered from ten 3-tree groups and combined into 10 corresponding samples. From each of these, ca. 300 nuts were cracked. A sample of 300 nuts was also cracked from each of the single tree plots for a grand total of 220 samples.

The first spring treatment series in the experimental orchard was timed using egg traps plus estimation of onset of egg hatch. A second spring treatment, if included, followed in 3 weeks. The hullcrack treatment was intended for the period of initiation of hullcrack. This period began July 7 (3% hullcrack on this date); however, the orchard was under irrigation and treatment was delayed until July 21 (70% hullcrack).

Egg trap data taken in early season in 8 Kern County orchards by Mr. Todd Crosby, Pest Control Advisor, were plotted, and these data and their implication in effective countywide timing of spring treatments are discussed later in this section.

Results.--Results of the large plot experiments are shown in Table 1. These results show very good reduction from early season applications against navel orangeworm. In comparing schedules, it is emphasized as noted above that the hullcrack treatments were delayed by irrigation. It is apparent from the results in Table 1 that this timing was too late.

The data in Table 1 show that the infestation at harvest by navel orangeworm in all 3 check areas of the orchard was evenly 28% which was the same level as the post-hullsplit treatment of Sevin, delayed by irrigation to 70% hullsplit. Early season treatments timed for onset of egg hatch were rather uniformly successful in suppressing this infestation to about 6%, the average level of control exerted being 79%, with no significant difference between early season treatment schedules.

Table 1. Comparison of schedules for control of navel orangeworm and peach twig borer, Nonpareil almonds, Richgrove, Calif., 1976.

Applications	Rate a.i./acre[1/]	Schedule: May 13	Schedule: June 3	Schedule: July 21 (Post-hullcrack)	Infested at harvest 8/25: Navel Orangeworm	Infested at harvest 8/25: Peach Twig Borer
1. Sevin 80W 2 spring treatments	5 lb	x	x	--	5.4%	0.6%
2. Sevin 80W 1 spring treatment 1 hullcrack treatment	5 lb	x	--	x	7.0%	0.7%
3. Guthion 50W 1 spring treatment and	2 lb	x	--		7.6%	0.6%
Sevin 80W 1 hullcrack treatment	5 lb			x		
4. Guthion 50W 1 spring treatment	2 lb	x	--	--	4.8%	0.6%
5. Guthion 50W 2 spring treatments	2 lb	x	x	--	7.1%	0.8%
6. Sevin 80W 1 hullsplit treatment	5 lb	--	--	x	28.2%	2.4%
7. TEPP 4E, 4 post-hullsplit treatments	1 pt, 1st 1 qt, 2d-4th[2/]			7/16, 7/20 7/24, 8/1	15.0%	2.4%
8. No treatment, southeast					28.3%	1.9%
No treatment, center-west					28.0% [handwritten bracket: 28%]	2.9%
No treatment, center-east					27.6%	2.8%

[1/] Active ingredient per acre except TEPP which is formulation per acre.

Two applications were not better than one and the two materials (Guthion and Sevin) were equivalent in navel orangeworm control at the rates used. All schedules which included a spring treatment also suppressed peach twig borer (see Table 1), averaging 0.7% in all schedules involving a May treatment. A light infestation was encountered, an average of 2.5% in untreated blocks. Post-hullcrack treatments did not affect twig borer damage (Table 1).

Four aircraft applications of TEPP were applied toward dusk in a 25-acre block at intervals of 4-8 days in the post-hullcrack period (Table 1). The series of 4 treatments was begun on 7/16 to provide for comparisons with other post-hullcrack treatments, delayed by irrigation. This was a handicap to the TEPP program, as it turned out that the timing was late. However, there was an apparent suppression of 54% of the navel orangeworm damage from this treatment series, which included an initial application of 1 pt TEPP followed by 3 of 1 qt TEPP each in 10 gallons of water per acre. Egg trap data taken in this treated area (75 traps) showed an 80% depression of egg laying during the periods between treatments as compared with egg traps (40) in an untreated block in the same orchard. Because the TEPP trial was unreplicated, the differences reported may in part be locational and less emphasis should be placed on the validity of these results than with the other schedules, which have been examined for 3 seasons and in several orchards by several investigators.

Another purpose of this trial was to observe effects of navel orangeworm treatments on mites and to examine whether inclusion of a miticide with early season treatments would be a worthwhile practice. Orchards of the area generally require one miticide treatment for two-spotted mite or Pacific mite. Two-spotted mite was prevalent in this orchard. Schedules for mite control are shown in Table 2. Plots receiving double treatments of Guthion and Sevin in early season were split in half and Omite added to half the plot with the first spring treatment and to the other half with the second spring treatment. A portion of two check plots was also treated with Omite alone at these different times to afford comparison.

Other scheduled uses of miticides were incorporated to provide various comparisons with standard usage. The standard schedule (Plot 4, Table 2) was composed of one spring treatment of Guthion followed by Omite when mites began to develop. Extensive two-spotted mite buildup began in mid-July throughout the orchard.

The following conclusions are drawn from results in Table 2.

1. No advantage resulted from including a miticide (Omite) with a spring treatment of Guthion for navel orangeworm. Such inclusion delayed mite buildup somewhat but did not avoid the necessity of a later treatment. (see 5B and 5A vs. checks A and C; check B vs. A and C, Table 2)

2. Best results for mite control always included a miticide treatment at onset of mite buildup (7/19-21).

3. Sevin has an adverse effect upon mite populations and it should not be used in spring treatments. Treatments at hullcrack combined with a miticide are acceptable. If Sevin is applied early with or without Omite, mites were not adequately controlled by a later application. (See 2B and 1A, Table 2). It is noted that mites are less well controlled by Plictran on 7/20 if Sevin was used early as compared with Plictran (7/20) when Guthion was used early (2A vs. 3, Table 2).

Table 2. Investigation of interrelationship of insecticide use for navel orangeworm with varied use of acaricides on control of twospotted mite, Nonpareil almonds, Richgrove, California, 1976.

	Material[1/]	Schedule of treatments 5/13	6/3	Post-hullcrack[2/] 7/21	Average mite rating[3/] 8/19	Average defoliation rating[4/] 8/19
3.	Guthion + Omite	X				
	Sevin + Plictran			X	1.2	1.5
4.	Guthion	X				
	Omite			X	1.3	1.4
6A	Sevin + Plictran			X	1.1	1.5
6B	Sevin + Omite			X	1.3	1.7
7	TEPP by air			XXXX	1.2	1.5
1B	Sevin	X				
	Sevin + Omite		X			
	Omite			X	1.5	1.5
2A	Sevin + Omite	X				
	Sevin + Plictran			X	1.6	1.8
1A	Sevin + Omite	X				
	Sevin		X			
	Omite			X	1.8	1.7
5A	Guthion + Omite	X				
	Guthion		X		2.3	2.1
2B	Sevin	X				
	Sevin + Omite			X	2.4	2.0
5B	Guthion	X				
	Guthion + Omite		X		2.6	2.1
Check	Omite	X			2.6	2.7
Check	Omite		X		2.8	2.8
Check	No Treatment				2.9	3.0

1/ Wettable powder formulations used: Guthion at 2 lb active ingredient (a.i.) per acre; Sevin, 5 lb a.i. per acre; Omite, 1.8 lb a.i. per acre; Plictran 0.7 lb a.i. per acre. Application at 375 gal. / acre, Bean speedsprayer.

2/ At this time mites were beginning to build up and this timing is that which is commercially used in the area for mite control.

3/ Mite damage rated on 54 trees in center area of plot using every 5th tree in every 3rd row. 18 trees were rated in the smaller check plots. Rating as follows: 1. Good 2. Medium 3. Severe.

4/ Ratings on 54 trees, etc. as above. 1. None to light 2. Medium 3. Heavy. Orchard under water stress enhancing effect of mites.

4. If Sevin is applied at hullcrack, addition of Plictran or Omite suppressed mites for at least a month (3 and 6, Table 1).

5. TEPP applied in 4 applications by aircraft suppressed mites for at least one month (7, Table 1).

Timing of early season treatment of Guthion.--Data in Figure 2 show that in Kern County in 1976, the time of onset of egg laying on egg traps was quite uniform in different orchards. These graphs, summarized in the lower graph in figure 2, show that eggs were quite uniformly detected by egg traps on April 26. These data suggest that the following procedure could be used to determine proper timing in a given county. A series of 5 egg traps could be installed in 5 orchards with a reasonably high mummy nut population. When navel orangeworm eggs are first found, to occur in most orchards, the eggs on the egg traps are circled with wax pencil and the infested egg traps are gathered together and hung in one orchard and watched for hatching. When hatching begins, a countywide advisory for application of a spring treatment could be made.

Comparison of new materials.--These were applied in 10 replications of single tree plots in full coverage sprays by hand at 70% hullcrack. Application was delayed by irrigation and results show that timing was late. Data in Table 3 demonstrate that the most active insecticide tested to date against the navel orangeworm is the synthetic pyrethroid SD 43775 (Shell Development). When applied at 0.2 lb per acre quite late in the hullcrack period (70%) the severe infestation (28%) was reduced by 50%. At this late timing, other materials applied at much heavier dosages (see Table 3) were successful in preventing only 25-30%, e.g. Imidan, Lorsban (at 4 lb/acre dosage), and Sevin.

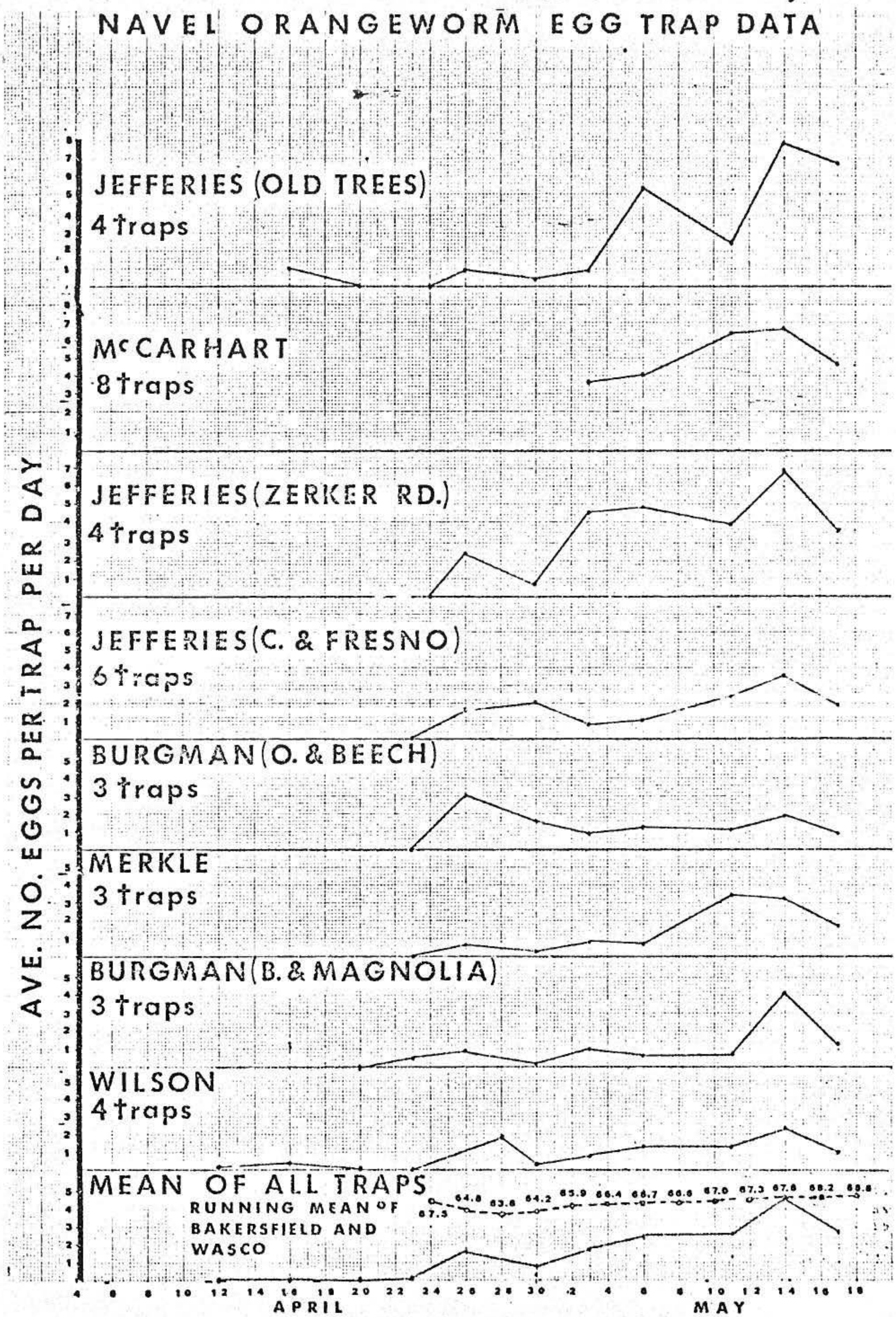


Figure 2. Egg trap data in several orchards in Kern Co. gathered by Mr. Todd Crosby, Pest Control Advisor.

Table 3. Comparison of larvicidal action against navel orangeworm provided by full-coverage spray in the post-hullcrack period, Nonpareils, Richgrove, Calif., 1976.

Treatment[1/]	Formu-lation	Active ingredient per acre (lb)[1/]	% infested kernels at harvest[2/]	Average mite damage rating[3/]
1. SD 43775	2.4 EC	0.2	14.5[4,5/]	1.2 (2)
2. Imidan	50 W	4.0	19.5[5/]	1.3 (3)
3. Lorsban	50 W	4.0	20.6[5/]	1.4 (4)
4. Sevin	80 W	5.0	20.9[5/]	2.1 (8)
5. Diazinon (encapsulated)	2 EC	6.0	21.9[5/]	1.7 (7)
6. Sumithion	40 W	2.0	23.6[5/]	1.5 (5)
7. Lorsban	50 W	2.0	23.8	1.7 (7)
8. Thuricide	3.2%	1.0	25.1	1.6 (6)
9. Uniroyal R677	0.5 EC	0.25	25.5	1.5 (5)
10. Monitor	4 E	4.0	26.1	1.4 (4)
11. Orthene	75 S	4.0	26.4	1.6 (6)
12. Gulf 5126	50 W	4.0	26.6	1.0 (1)
13. Untreated	-	-	27.7	2.3 (9)

[1/] Applied by handgun 7/20-21 in 1000 gal/acre to 10 single tree replications in randomized blocks. Application at 70% hullcrack delayed by irrigation.

[2/] Average of harvest samples, 300 nuts from each of 10 trees.

[3/] All trees rated on 8/18 for twospotted mite damage, 1 = none to little; 2, medium; 3, severe. Numbers in parentheses are the rank-order.

[4/] This treatment better than treatments 7-13 at 19:1.

[5/] These treatments better than check at 19:1.

Two-spotted mite development was just getting underway at the time of these treatments and ratings were made one month later on effects of mite populations. It will be seen (Table 3) that at the dosage used (4 lb per acre), Gulf 5126 prevented further mite development. It is also noted that the Shell Development compound did not stir up a more severe mite population but tended to suppress it.

Trial of Microencapsulated Methyl Parathion against Navel Orangeworm on Almonds

Lodewyk P. S. Kuenen
Department of Entomology
University of California, Riverside

In 1976, Microencapsulated Methyl Parathion-Pencap M™ (MMP) received a State of California experimental label on almonds. The label requires the application of MMP prior to the onset of hullcrack. This test was conducted on 20 trees of Merced almonds in a 130-acre block of almonds in Tulare County. The test consisted of a randomized block designed with 10 pairs of similar trees, one receiving a MMP treatment, the other no treatment. The nut trees were paired on the bases of similar size, foliage, and nut set. The tree to be sprayed with MMP in each pair was assigned randomly. Immediately prior to the application 40 nuts were sampled at random from each test tree and examined for hullcrack which was recorded at 2%.

On August 8, 1976 the MMP (2 lb active ingredient/gal) was applied by handgun at the rate of 6.4 fluid oz/100 gal of water and 1000 gal per acre.

To assess effects on mite populations, leaf samples were taken from the test trees on August 17, 9 days after application. Ten leaves were randomly selected from each tree yielding 100 leaves/treatment. The leaves were brushed with a leaf brushing machine, the mites being deposited on a circular glass plate. A count for two-spotted mites and citrus red mite, Panonychus citri McGregor, was conducted on 10% of the area of each plate.

On September 27, the test trees were harvested by handknocking the nuts onto canvas. By rolling the canvases toward one end of the trees the nuts collected into a pile from which 300 nuts were taken randomly. These nuts were stored at 40°F from September 28 until October 18, when crackout commenced and the number of nut meats infested by the NOW was recorded.

Results.--The crackout yielded a 12.2% infestation rate for the control trees, while the MMP trees had a 9.7% infestation rate. A T-test for paired observations was performed which indicated that there was no significant reduction of nut meat infestations at the .10 level of significance.

The mite count taken 8/17/76 indicated MMP-treated trees had 46.4 two-spotted mites/leaf and 3.2 citrus red mites/leaf, while the control had 53.2 two-spotted mites/leaf and 4.9 citrus red mites/leaf, showing no significant effects.

Studies on the Dispersal Ability of the Navel Orangeworm, *Paramyelois transitella* (Walker)

K. L. Andrews and M. M. Barnes
Department of Entomology, U.C. Riverside

Summary.--Navel orangeworm, *Paramyelois transitella* (Walker), dispersal was studied using two different but complimentary methods in 1976. First, the pattern of infestation in a large block of pistachios adjacent to a block of heavily infested almonds was studied in September. A regression line describing the observed infestation rate as a function of distance from the original locus of infestation was calculated. Using the slope of the regression line estimates of the impact of immigrant moths from an adjacent orchard on a sanitized orchard can be made. It was determined that navel orangeworm infestation rates diminish logarithmically with distance. The infestation at one-half mile from a source of infestation was about one-third of that observed adjacent to the source of infestation. Infestation one mile from a source would be 1/10th of that directly adjacent to the source.

A second method involved the rearing of navel orangeworm larvae in the laboratory on a Calco Oil Red-stained media. The internally marked females which emerged from this media were released into an almond orchard. Movement of the females was traced by noting the presence of Calco Oil Red-marked eggs on oviposition traps arranged regularly at various distances around the release site. Two separate releases were made. The first study was conducted in late June when warm summer conditions prevailed and lasted five nights. The second study lasted from September 22 till October 1. Conditions were unseasonably cool and wet during the course of the latter study.

Because of design and weather problems, the results of these tests allow us to answer the question, "How far do navel orangeworm female moths fly?" only tentatively. However, much useful information concerning navel orangeworm field biology was gained through these two releases. In the first test, it was shown that navel orangeworm moths fly only during the period from sunset to sunrise. They oviposit primarily during the early hours of the night. During the first night of their adult life they lay no eggs. Almost all the eggs which they will lay are deposited during their second night of adult life. Navel orangeworm moths demonstrated a strong propensity to fly into the night wind; over two-thirds of the marked eggs found were recorded from the one-third of the traps which were located upwind of the release site. In the second marked moth release the colder temperatures restricted moth activity significantly; the moths flew during the first few hours of the night only and all egg-laying activity was restricted to a very short period immediately after sunset. Thresholds for oviposition and flight appear to be ca. 65° and 60°F, respectively. Egg laying again commenced on the second night after emergence. Oviposition activity continued for 6 nights at which time the study was discontinued. Directed movement into the wind was once again observed.

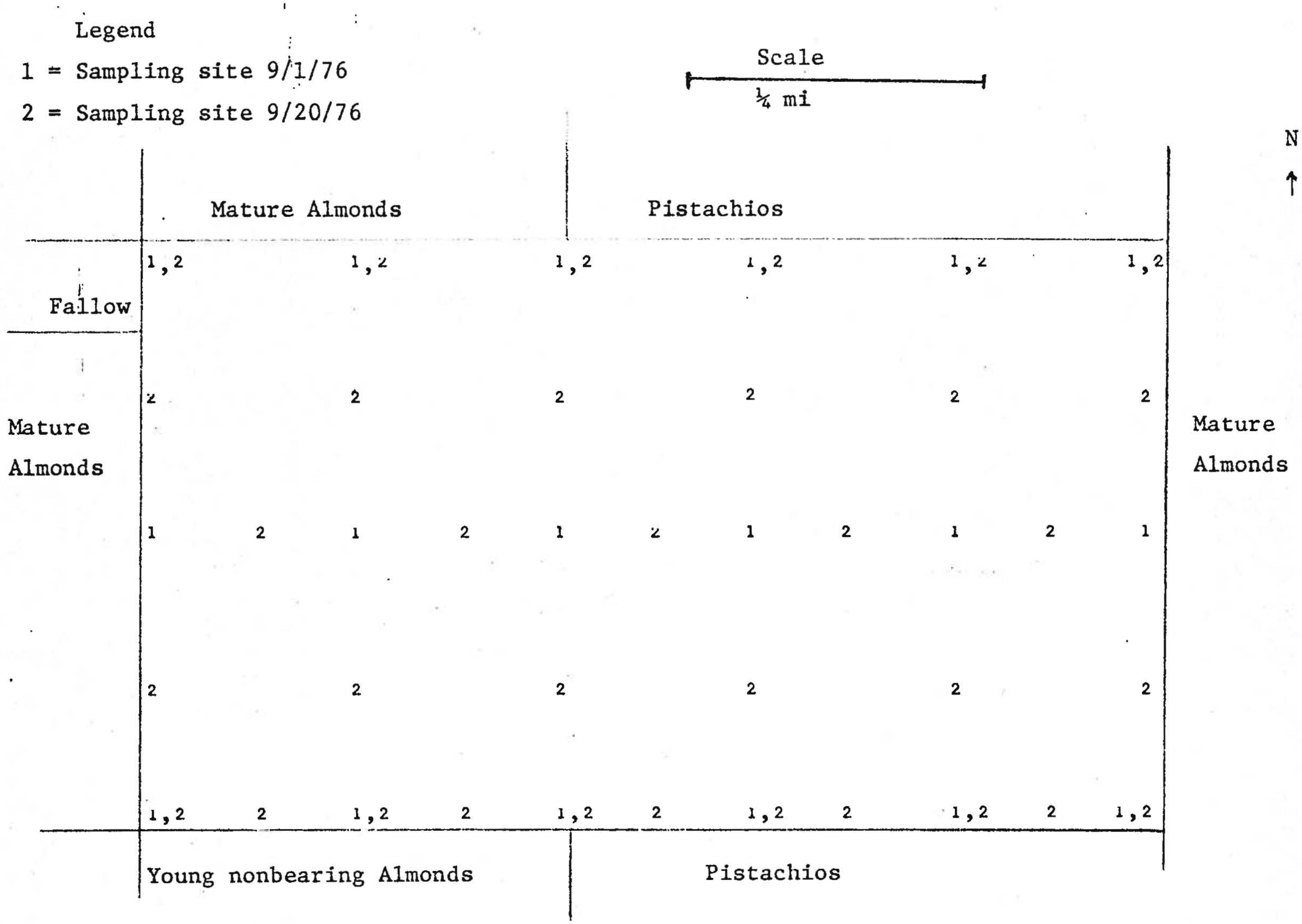
I. Determination of Dispersal Ability of the Navel Orangeworm by Observation of the Colonization of an Uninfested Pistachio Orchard.

The navel orangeworm finds pistachios to be an attractive and nutritious host. Observations in several different orchards over the past two seasons have shown that the navel orangeworm has the ability to move rapidly into uninfested pistachio orchards at the time of hullsplit and cause significant damage to the maturing pistachio crop. This damage is especially severe in portions of orchards in close proximity to external sources of navel orangeworm, most notably heavily infested almond orchards. The degree of damage diminishes progressively as one moves from the periphery into the orchard. Thus, by making infestation counts in a large, previously uncolonized pistachio orchard which was bordered by heavily infested blocks of almonds on 2½ sides we could measure the dispersal ability of undisturbed natural populations of navel orangeworm moths in the field. From the resulting data a regression line of percent infestation on distance was calculated.

Materials and Methods.--The block of pistachios used in this test is owned by Blackwell Land Co. and is located 12 miles to the west of Lost Hills, Kern Co., California. It is in the area of large plantings of almonds (16,000 acres) which is subject to significant navel orangeworm damage year after year. The pistachio block measures 0.5 miles from north to south and is 0.85 miles from the east to west and contains 275 acres. A gently sloping hill dominates the NW fourth of the block, while the remaining portions of the orchard are flat. Mature almonds are planted along the eastern and western borders of the plot. In addition, almonds are planted along the western half of the northern border (See Figure 1). The pistachios were planted in 1971, and trees had their first nut crop in 1976. The trees would have borne a small crop in 1975 but for a late spring freeze. The trees vary somewhat in size depending on terrain and soil conditions, but they average about 10 feet in height, so they are very large trees to be having their first crop.

Because this year's crop was the first, there was no resident navel orangeworm population in the blocks; any infestation which was

Figure 1. Map of Pistachio Plot Used for N.O.W. Dispersal Study, Blackwell Land Co. Lost Hills, Kern Co., Calif., 1976.



observed soon after hullsplit had to be the result of the activity of female moths which had flown in from outside the block. Later in the season, after the first pistachio-bred generation had matured, some of the infestation clearly would be due to sources within the orchard. As will be shown, however, the observations currently under discussion were completed before this became a problem.

Small samples consisting of 100-200 nuts were collected on August 1, 9, and 20. On September 1, when hullsplit pistachios could be found rather easily, 50 hullsplit pistachios were collected from 5 to 10 trees in each of 18 areas (see Figure 1) and checked for infestation within 24 hours. The numbers of larvae, pupae, and pupal cases were recorded.

On September 20, the same basic procedure was followed, except that 150 hullsplit nuts were collected from each of 34 areas (see Fig. 1) and stored in paper bags at 40°F until they could be cracked out and checked for infestation.

Results and Discussion.--The small samples taken early indicated that infestation of the pistachios commenced about August 20 when hulls first began splitting. The results of the September 1 collection are presented in Table I. Because of the small number of sample points, the small sample size and the fact that the infestation was just getting underway, it is difficult to determine what kind of relationship existed between percent infestation and distance from the almonds on the west. The almonds to the east do not seem to have served as a significant source of immigrant moths. A gradient does exist from north to south, but since only 3 points are available a reliable regression line cannot be calculated. There is little point in dwelling on these data since the

Table I. Percent infestation[1/] at various sampling sites in pistachio blocks on September 1, 1976, Blackwell Land Co., Lost Hills, California.

Row	Sampling Location[2/] 1	2	3	4	5	6	Mean
Northernmost	22	26	6	6	2	0	10.3
Central	6	6	0	0	2	2	2.7
Southernmost	0	4	2	0	4	0	1.7
Mean	9.3	12	2.7	2	2.7	0.7	

1/ Based on 50 hullsplit nuts per site

2/ 1 is westernmost site. 6 is easternmost site.

results of the September 20 collection as presented in Table II are much more amenable to interpretation. It should be noted, however, that of 61 navel orangeworm individuals encountered on September 1, only one appeared to be older than third instar. Most were either first or second instar. This demonstrates that the first generation breeding on pistachios was far from reaching a reproductive stage. Thus, none of the infestation present can be attributed to activity of female moths which developed on pistachios. The situation is similar for the September 20 count; only two pupal cases and 12 pupae were found in 318 infested nuts.

When totals for September 20 were calculated, the northernmost six observations found in Table II were disregarded because of the impact of the almond source at the northeast edge of the pistachio block. The natural log of the column totals for the remaining infestation counts is presented in Figure 2 as a function of distance from the western block of almonds.

The calculated regression line is:

$$l_n\, Y = 2.324 - 2.13\, X$$

where, X = distance in miles

Y = percent infestation

The easternmost mean value was excluded in the calculation of this line because the average infestation at this distance was so high. It was higher, in fact, than the preceding seven means. Almost certainly, this was a border effect which can be attributed to oviposition by moths from the orchard to the east.

Table II. Percent infestation[1/] at various sampling sites in pistachio block on September 20, 1976, Blackwell Land Co., Lost Hills, CA.

Row	Sampling Location[2/] 1	2	3	4	5	6	7	8	9	10	11
A[3/]	15.0	-	17.3	-	4.0	-	4.0	-	6.7	-	10.0
B	2.3	-	10.7	-	7.3	-	5.3	-	2.0	-	3.3
C	-	8.7	-	8.0	-	6.7	-	3.3	-	0.7	-
D	18.7	-	4.7	-	2.0	-	2.7	-	2.7	-	3.3
E	17.3	10.0	5.3	2.0	0.0	2.7	2.7[4/]	2.7	4.0	3.3	4.7
$\bar{x}$ including Row A	13.3	9.4	9.5	5.0	3.3	4.7	3.7	3.0	3.9	2.0	5.0
$\bar{x}$ excluding Row A	12.8	9.4	6.9	5.0	3.1	4.7	3.5	3.0	2.9	2.0	3.8

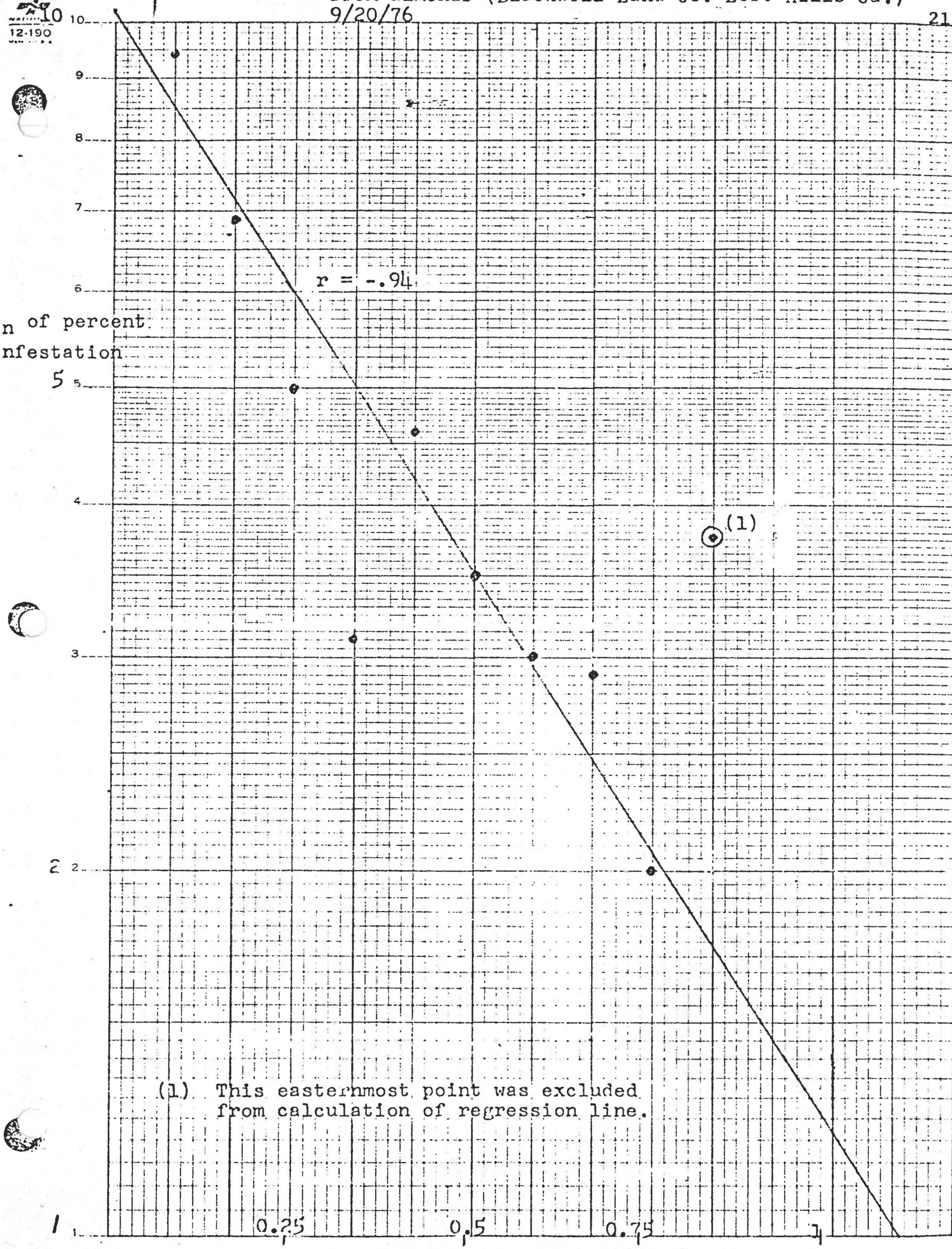
1/ Based on 150 hullsplit nuts per site.

2/ I is westernmost site. 11 is easternmost site.

3/ A is northernmost row. E is southernmost row.

4/ Value was estimated.

from almonds (Blackwell Land Co. Lost Hills Co.)
9/20/76



From this it can be seen that there were one-half as many infested nuts at .34 miles as there were adjacent to the almonds. Twenty-five per cent as many nuts were damaged at .67 miles as at zero miles. If the regression line is extrapolated, it indicates that the infestation levels found one mile from the source of infestation would be approximately one-tenth that observed at the source of infestation.

It would be unwise to decide that the conclusions drawn from these observations can be generalized to all navel orangeworm populations under all conditions. First of all, dispersal must surely be influenced by such factors as temperature, host fruit densities, stage attractiveness of fruits, and wind speed and direction. Second, only local dispersal was studied in these observations and the results do not directly demonstrate the ability of navel orangeworm moths to move long distances.

Note also that the movement observed in this study appeared to be largely from west to east. The easternmost counts taken on trees only 30 meters to the west of almonds was very low. This may be explained by the fact that the almonds to the west and north were knocked to the ground in late August while the almonds to the east of the pistachios remained in the trees until about September 12. Female moths upon emerging fly in the canopy. In the unharvested orchard to the east they would have easily encountered oviposition sites and so were likely to deposit their eggs there; they were, in essence, "trapped" in this orchard. Female moths emerging from grounded nuts in the almond orchard to the west, on the other hand, would have encountered far fewer suitable oviposition sites in the trees and could therefore have moved out of the orchard either by random movement or by orienting to olfactory signals emanating from the hullsplitting pistachios in the adjacent orchard.

Alternatively, the gradient observed may be due to the positive anemotactic (air-movement) response navel orangeworm females exhibit. This assumption will be looked into in some detail in the following section on dispersal studies involving release and detection of Calco Oil Red-marked moths.

II. Determination of the Dispersal Ability of the Navel Orangeworm through Mass Release of Calco Oil Red-Marked Female Moths.

A second procedure for measuring the dispersal ability of the navel orangeworm promises to be more generally useful than the method just discussed. This procedure involves the laboratory-rearing and field release of large numbers of navel orangeworm moths which have been marked internally with a powerful red dye. The movement and oviposition behavior of the released marked moths are monitored by daily checking oviposition traps hung in a regular arrangement around the release site for the presence of dyed eggs. These dyed eggs are initially a coral pink color and are easily distinguished from wild eggs, which are cream-colored when first laid. After 24 hours both the wild and marked eggs take on a pink-orange hue and are indistinguishable.

In 1976 this method was tried twice. Neither test allows us to answer conclusively the question of primary importance to us, i.e. what percent of the eggs deposited by a female will be found at any given distance from the site at which the female developed and emerged? Despite this, the tests must be considered net successes for three reasons. First, the method itself was shown to be sound and effective beyond our original expectations. Second, information which allows tentative conclusions about the flight ability of moths was gathered. Third, data yielding valuable information about navel orangeworm flight and reproductive behavior was gained.

Release 1--June 22-27, 1976

Materials and Methods.--Mummy almonds were collected from a heavily infested orchard 6 miles east of McFarland, Kern Co., California, during the first few days of May. These nuts were taken to Porterville, Tulare Co., and put under pyrimidal emergence cages. Moths which emerged were collected daily and put into 1-gal oviposition cartons. Paper toweling upon which female moths could lay eggs was secured over the ends of these cartons. Towels were collected when most of the moths in the cartons were observed to be dead, which was generally after two or three nights. The towels bearing eggs were then stored at 40-45°F and at high humidities until May 15. On this date they were removed from the cold chamber and put into containers filled with dyed media made in the manner described below.

One part of unprocessed clover honey was thoroughly mixed with one part glycerol and one-half part water. One tablespoon of Brewer's yeast for every gallon of this liquid mixture was stirred in. Seventy-eight thousandths oz of Calco Oil Red N1700™ (American Cyanamid Co.) was dissolved in ca. 30 ml heated Mazola™ corn oil and added to each gallon of liquid. One part of this dyed liquid was then added to 4.8 parts of red wheat bran and mixed until the bran was thoroughly and completely impregnated with the liquid. The result was the standard navel orangeworm rearing media except that it contained .025% Calco Oil Red by weight.

From May 15 till June 22 the cultures were maintained in Porterville at ca. 80°F. On June 22 they were taken to the McFarland orchard for the first night's release. The cultures were gently uncovered at ca.

7:30 p.m. Approximately 800 moths emerged from the media and dried their wings during the late afternoon and evening. These moths began flying at twilight which occurred about 8:30 p.m. Most had left the media by 9 p.m. An additional 500 moths which had emerged between June 18 and June 21 were also uncovered at 7:30 p.m. These moths had been collected daily and stored in gallon containers at 45-50°F until the afternoon of June 22 when they, too, had been taken into the field. Most of these moths had been damaged in the storage process and only a small number of them (perhaps 100) were able to fly away.

On June 23 approximately 800 more internally marked moths, which had emerged that afternoon and evening, were released from the same site. The cultures were taken out of the field on the morning of June 24.

The trap layout (Fig. 3) is easily visualized as an 8-pointed star in which the middle third of every other ray has been pulled out, pivoted, and repositioned a short distance away from the main ray. This trap arrangement was chosen in order to allow us to decide on the basis of this first release if the moths were "trap-hopping".

The terrain throughout the test area was rolling with the exception of the distal half of the west trap line which was flat. The release site was situated on a hillside which sloped gently downward to the west and the south. The downward slope to the north was steeper while the incline was gradually upward to the east of the release site.

Egg traps were hung 6-7 ft high in the NE quadrant of all trees, as marked in Fig. 3. Trees were 20 ft apart in the N, E, S, and W trap lines. In the NE, SE, NW, and SW trap lines, the first ten traps were ca. 28 ft from each other, the next eight were ca. 45 ft apart, and the last 11 were again spaced at 28-ft intervals. All trap lines were 1000 ft long;

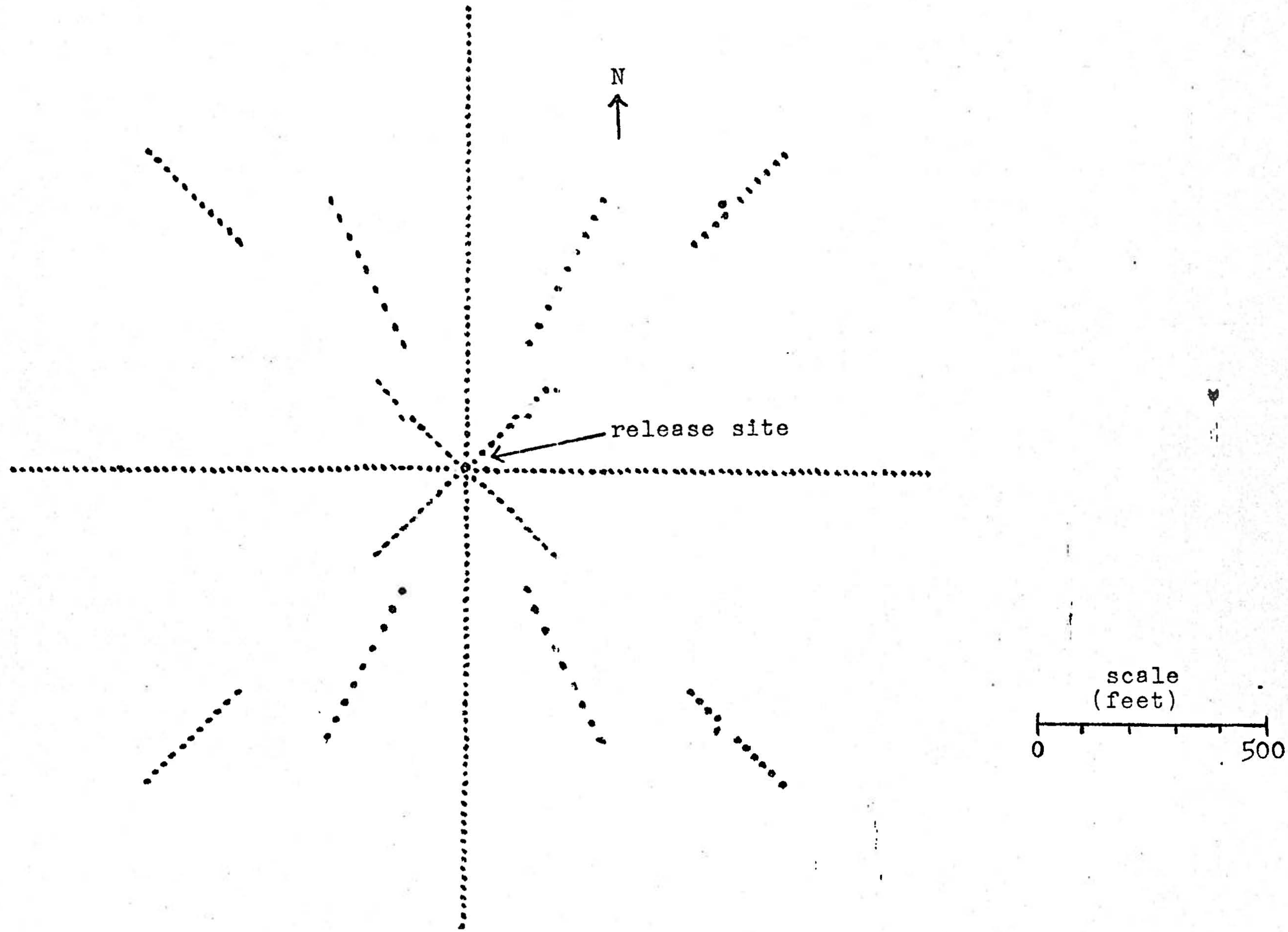


Figure 3. June 1976 dispersal study. Trap layout, McFarland, Calif.

thus, there were 50 traps in the N, E, S, and W lines and 29 traps in the remaining four lines.

Traps hung in trees on June 22 were checked on June 23 for the presence of both coral pink colored eggs laid by marked females and for beige wild eggs. Any eggs observed were crushed and the number on each trap was recorded. The traps which contained day-old media were then replaced with clean traps containing fresh media. These fresh traps served as oviposition sites on the night of June 23-24. On June 24 these traps were checked and replaced with traps containing fresh media. These latter traps were the same ones which had been taken down on June 23; they had been checked and cleaned twice--first on the 23rd and then again on June 24--before they were refilled with media. By this procedure we could be certain no day-old pinkish wild eggs would be mistaken for eggs recently laid by marked females.

Results and Discussion.--Fig. 4 shows the average number of marked eggs laid per trap for each trap line. These averages are for the 5-night period of June 22-27. In this figure the averages are presented not only numberically but also as lines of varying lengths; the length of the line is an easily visualized graphic representation of the average number of eggs per trap in each particular trap line. It may be seen from these data that traps in the three eastern trap lines (NE, E, and SE) received ca. 4.5X as many marked eggs as the traps in the three western trap lines (NW, W, and SW). Traps directly to the N or S of the release site also received a low number of eggs per trap.

Fig. 5 presents another feature of the marked egg distribution which resulted from this release. In this figure the reader may find isograms indicating the distances from the release site within which various pro-

Figure 4. June 22-27, 1976 Dispersal Test. Graphic and numberical representation of the average number of Calco oil red-marked eggs per trap for each trap line for the 5-day period, McFarland, Calif.

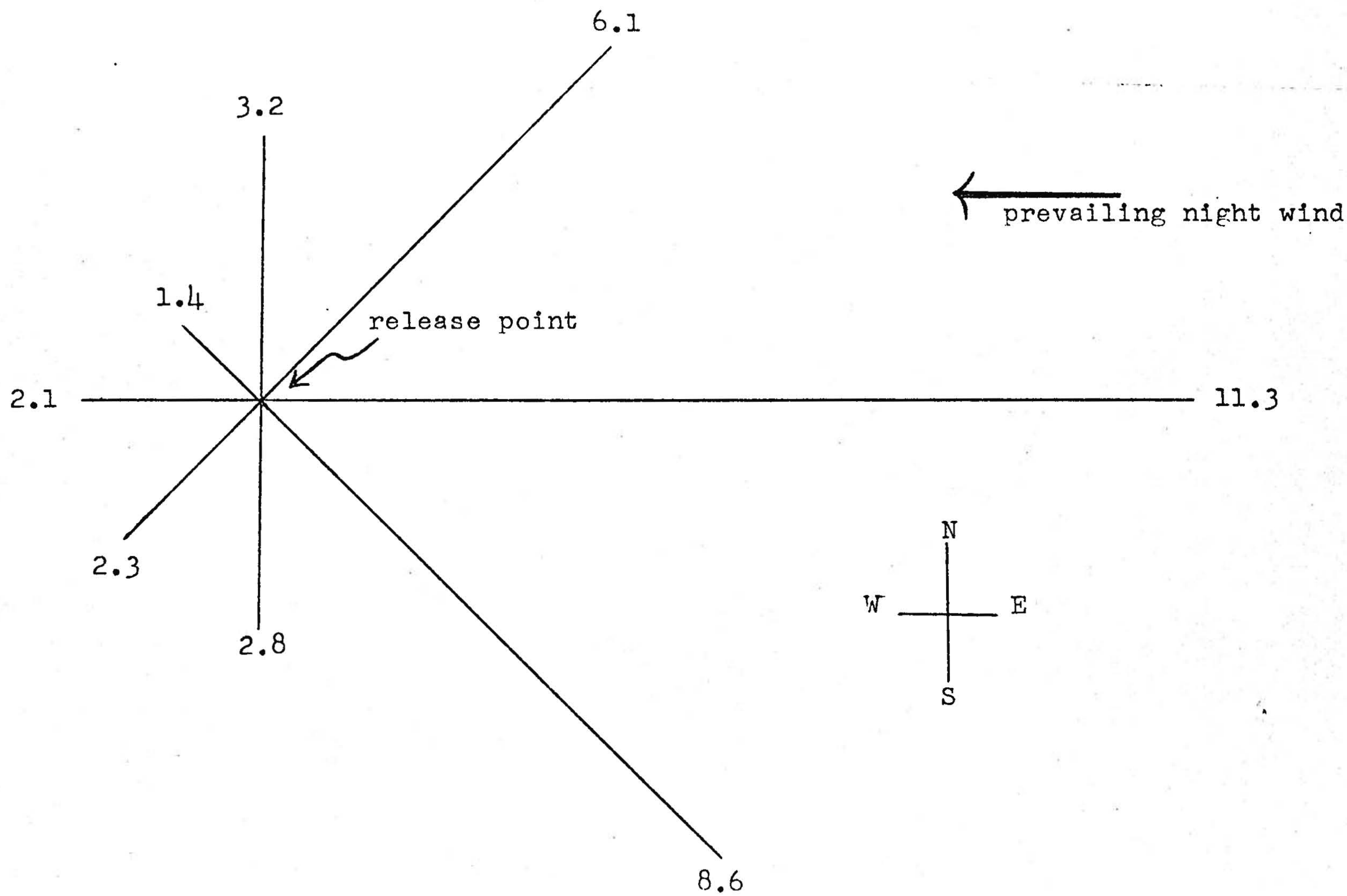
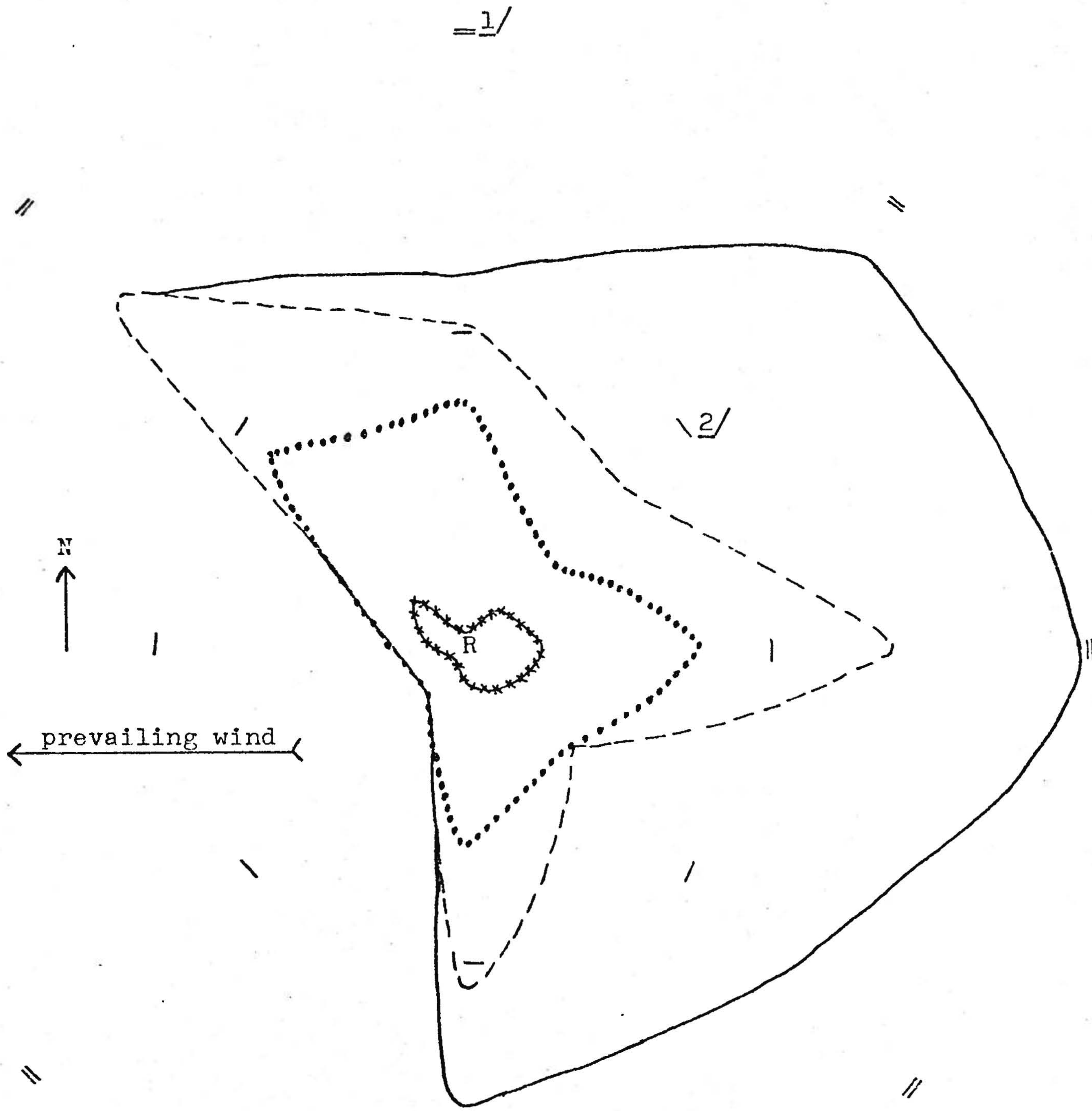


Figure 5.--June 1976 Dispersal Test. Distances within which 50, 90, 95 & 100% of the Calco Oil Red marked eggs were found on each trap line.



1/ 1,000 feet from release site

2/ 500 feet from release site

portions of the eggs recorded were found. For instance, along the E trap line, 50% of the total number of eggs found were recorded from the six traps which were 120 ft or closer to the release site. Ninety percent of the eggs found along this trap line were found within 380 ft of the release site. Ninety-five and one hundred percent were found within 700 ft and 980 ft, respectively. This contrasts strikingly with the situation on the W trap line where 50% of the eggs were found within 60 ft of the release site and 100% within 120 ft.

While the information presented in this figure is useful, it is misleading in two ways. The prominent bulge seen along the NW trap line represents nothing more than the fact that 4 of the 41 marked eggs found along this trap line were found at 792 ft; no other marked eggs were found beyond 448 ft. If this single record could be disregarded, the overall distribution would be much clearer, i.e. there would be a clearcut pattern in which it could be seen that eggs on the W trap lines tended to be laid much closer to the release site than eggs along any of the other trap lines.

Second, and much more important, the reader must realize that the shape of the distribution is to some extent an artifact of the trap layout. Had the trap lines been longer, especially to the E, one would have obtained a much better idea of the actual distribution and extent of egg laying. Almost certainly the isograms would be extended much farther to the E had the traps extended farther. On the other hand, little or no extension would be expected to the W, N, or S had the trap lines in these directions been extended.

It will be seen from the information in Figs. 4 and 5 that there was a very pronounced eastward movement of moths in this test. Over two-thirds of the eggs recorded were found on the third of the traps to the E. Distances traveled by the moths were also noticeably farther to the E than in other directions.

Wind spread and direction information was gathered during the course of the test. This data indicates that daytime winds were predominantly from the N and W, while nighttime winds were gentle easterly drainage winds.

Table III shows moth flight as a function of time of day and night. This information clearly demonstrates that moths began to fly only after sunset and stopped some time before sunrise. Thus, only the easterly nighttime winds were likely to affect navel orangeworm flight behavior in any way.

A reasonable hypothesis to explain the directed movement of the moths, based on response to wind direction, may now be developed. Navel orangeworm moths find oviposition sites by responding to volatile substances emanating from suitable fruits. Such olfactory signals can be present at significant distances, of course, only downwind from their source. Moths, therefore, must move predominantly upwind as they home in on oviposition sites; they are, in effect, "pulled" into the wind. This process, usually referred to as positive anemotaxis, provides a plausible explanation for the directed movement of the released moths.

The data gathered in this release trial do not allow us to estimate directly the flight capabilities of navel orangeworm moths. This is because the declining number of eggs found as distance from the release site increased was the result of two separate and confounded phenomena. First, the number of females which reached distance traps was less than the number which passed traps close to the release site; this was, of

Table III. June 1976 Dispersal Study. Total number of navel orangeworm moths caught in Pherocon 1C™ sticky traps during different periods of the night[1/] and temperature (°F) at the ends of the periods. McFarland, Calif.

Night of:		7 PM	8	9	10	11	12	1 AM	2	3	4	5	6	7	8	
6/25-26	Temp.		83°		3/				69°				67°		80°	
	No. caught	0		9			13				4			0		0
6/26-27	Temp.		78°		75°	72°		72°		66°			65°		83°	
	No. caught	0		4	10		8		15		3			0		0

Time of Night[2/]

1/ Based on 10 sticky traps hung in trees 50-200 ft to the ESE of release site.

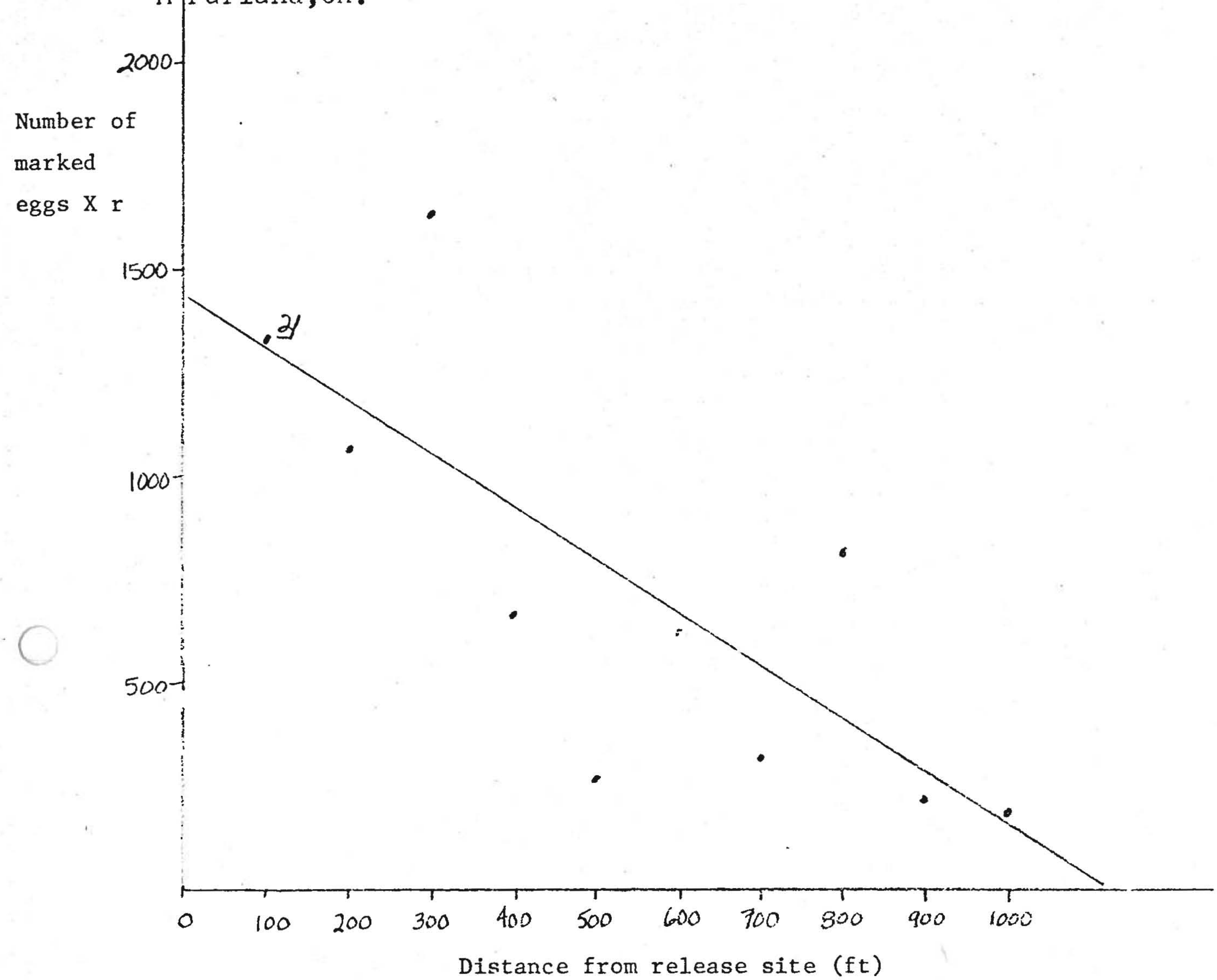
2/ Sunset occurred at 8:30 p.m. Sunrise occurred at 5:30 a.m.

3/ Temperature not recorded.

course, the very gradient we hoped to measure in this dispersal test. Unfortunately, the second factor, decreasing trap density, complicated our interpretation. Traps at 1000 ft were trapping areas which were many times larger than those which traps set at 20 ft did. The chance for moths to pass any particular point undetected therefore increased as distance from the release site increased. It is necessary to find some correction factor which will adjust counts in a manner which compensates for progressively decreasing trap density before we can interpret the data.

In one approach the raw data is corrected by r, where r = distance from release site to the trap/site. As discussed above, the moths are flying predominantly from W to E as they search out oviposition sites. This means that it is more appropriate to think of the length of the arc (or portion of the circumference of a circle) which any single trap must service rather than the area it must service. In Fig. 8 the number of eggs multiplied by r (and then divided by 20 to reduce all values by their least common denominator) for 100-ft sections of the N, E, S, and W trap lines are graphed against distance from release site. Considering only this linear relationship, it is indicated that no eggs would be laid beyond 1160 ft. However, the possibility that a logarithmic relationship best describes the situation is worth consideration especially since the log relationship held so well in the pistachio dispersal study.

Figure 8 -- June 1976 dispersal study. Total number of marked eggs multiplied by r[1/] on 100 feet sections of N,E,W,&S trap lines plotted against distance from release site. McFarland,CA.



1/ r is the distance of the trap from the release site in feet.

The natural log of the number of eggs times r is plotted against distance from release site in Fig. 9. The regression line (r = -0.80) is:

$$l_n Y = 7.48 - 0.22 X$$

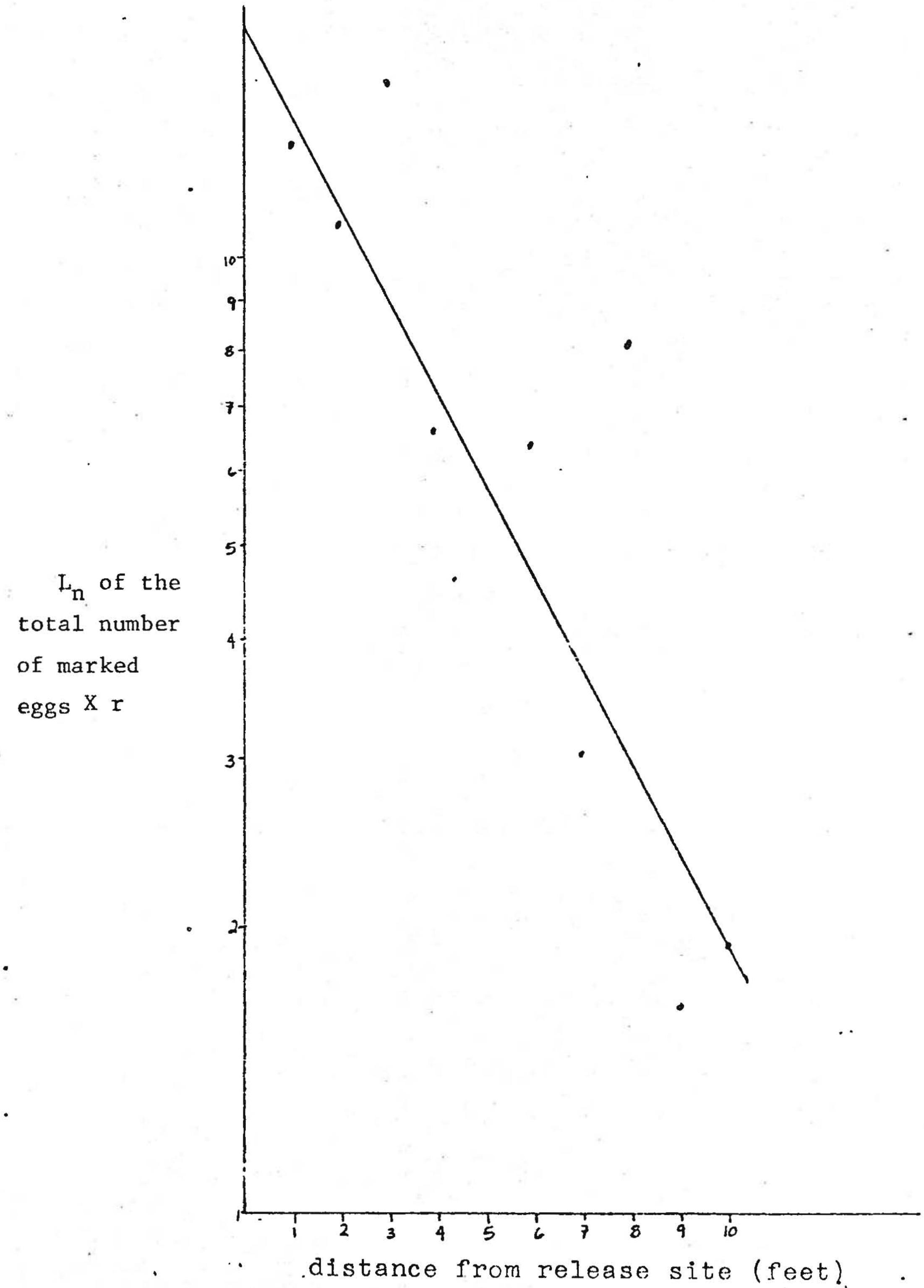
where X = distance from the release site in 100 ft

Y = number of eggs x r

This regression line when extrapolated predicts that no eggs would be laid beyond 0.64 miles under conditions similar to this trial.

Information on oviposition behavior can be developed from the data above. Fig. 10 presents the mean number of marked and wild eggs per trap for each of the five nights. The number of wild eggs stayed approximately constant for all five nights, indicating equally favorable meterological conditions. However, virtually no marked eggs were found the first night; apparently the moths required a period of one night during which time they mated and matured their eggs. On the second night of their adult lives they began ovipositing. Presumably the moths released on the 23rd behaved in the same way. That is, they began laying eggs on the night of June 24-25. If this was the case, they laid almost all the eggs they would lay in that one night; few marked eggs were recovered after the night of June 25-26, and virtually none were found after June 26-27. This indicated that under the kinds of environmental conditions which prevailed during this test (see Table IV) navel orangeworm moths lay significant numbers of eggs only on the second night of their adult life. They either lay almost their entire complement of eggs at that time or else they die prematurely.

Figure 9.--June 1976 dispersal study. Natural log of the total number of marked eggs multiplied by r[1] on 100 feet sections of N,E,S,&W trap lines plotted against distance from release site. McFarland, CA.



1/ r is the distance of the trap from the release site.

Figure 10.--Mean number of eggs per trap for each of the 5 nights of the June Dispersal Test. McFarland, California 1976

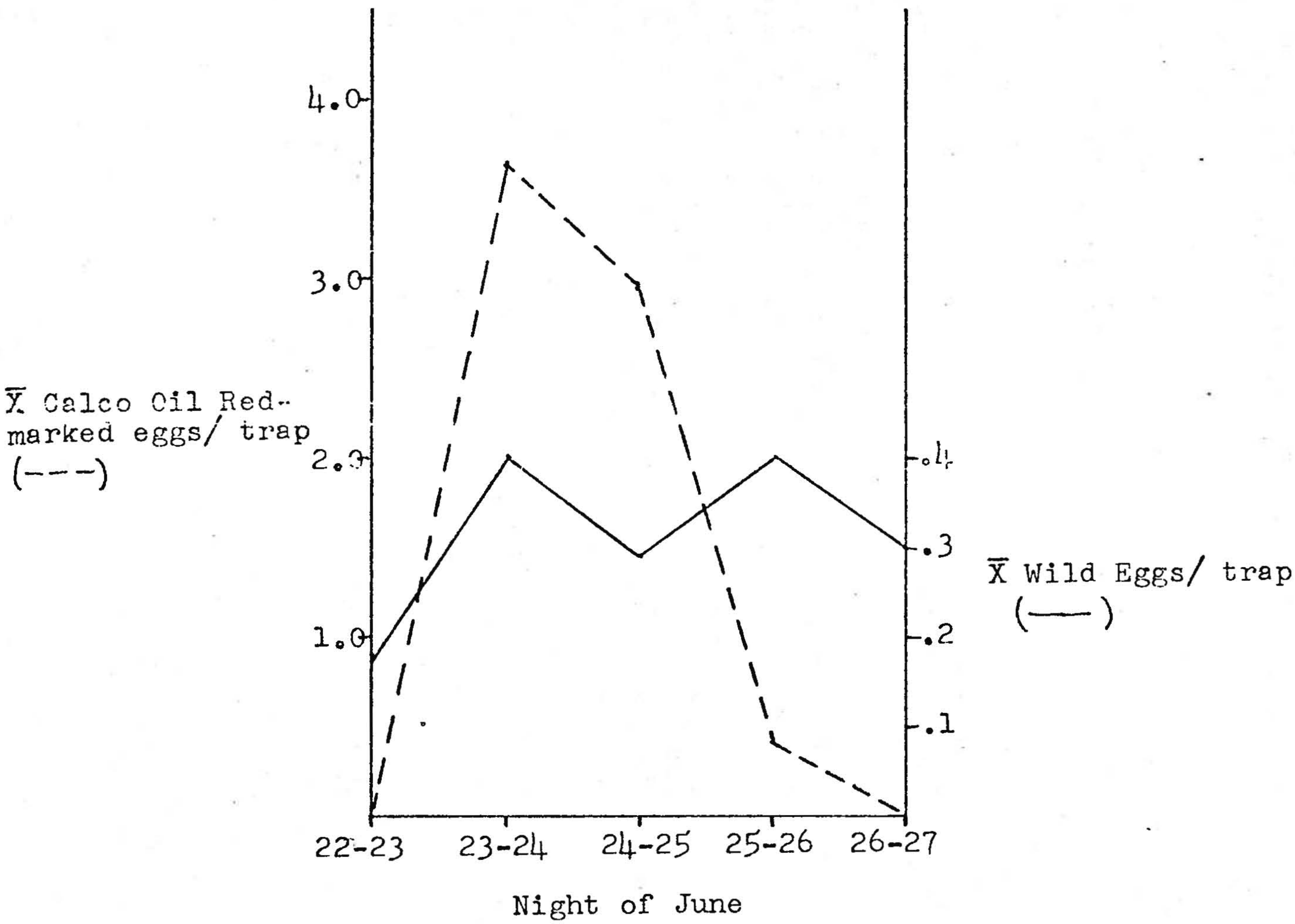


Table IV. Maximum, minimum and sunset temperatures (°F) for the June dispersal test[1/].

Date	Temperature (°F)		
	Minimum	Maximum	Sunset
June 22	-	-	75
June 23	66	98	76
June 24	68	101	82
June 25	66	100	83
June 26	67	102	78
June 27	65	104	-

[1/]Readings made on the northern side of a tree near the release site about 6 ft above ground.

Table V shows that while some oviposition took place all night, most eggs were laid before 2:00 a.m. Flight activity, on the other hand, continued throughout the night (Table III).

Release 2--September 21 to October 1, 1976

Materials and Methods.--Marked moths were reared in a manner identical to that used for the June release. The cultures were taken to the McFarland orchard on the afternoon of September 21 and the moths which emerged that evening were released. Moths were released again the following night after which time the colonies were taken out of the field.

In order to avoid the problems generated by the use of the star-shaped layout, the trapping design shown in Fig. 11 was employed. This design was a gridwork of traps placed in such a manner that throughout the test area trap density was constant. Because the moths moved so predominantly in an eastward direction in the 1st test, traps were placed farther to the east of the release site than to the west.

The release site was situated near the bottom of a wide depression. To the north, east, and south, hilly terrain prevailed while the depression extended and widened to the west. The anemometer was situated ca. 800 ft to southeast of the release site on a west-facing hillside. Traps were checked and replaced daily as in the June test.

Results and discussion.--Prevailing conditions during the September test were much cooler and wetter than during the June study. These conditions restricted the activity of the moths to a great degree. Table VI shows that oviposition was restricted to the hour following sunset; presumably it became too cool after that time for oviposition. Flight

Table V. June 1976 Dispersal Study. Total number of marked eggs laid during different periods of the night[1/] and temperature (°F) at the ends of the periods. McFarland, Calif.

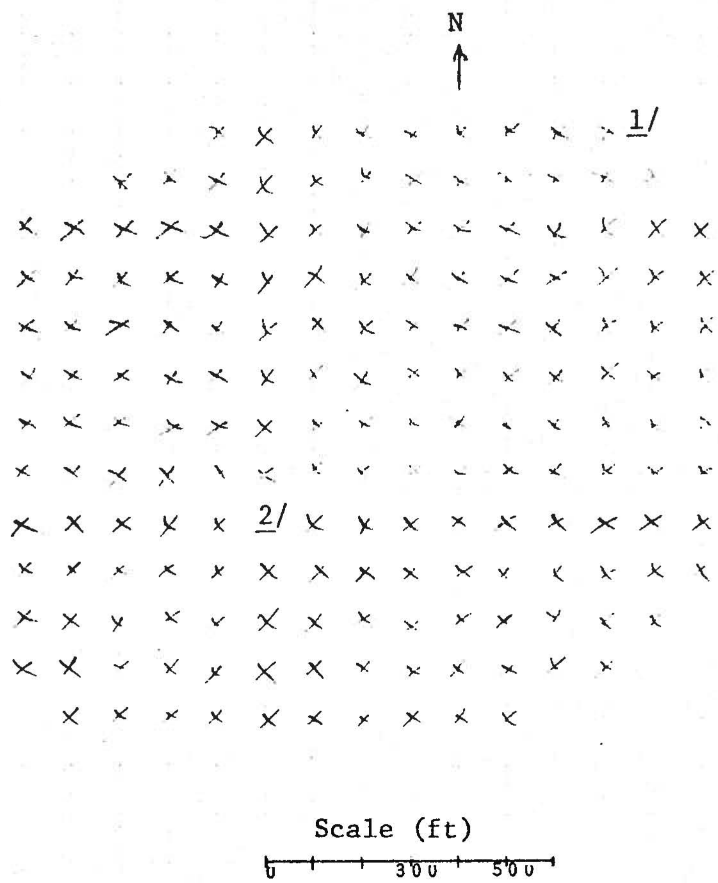
		Time of Night[2/]													
Night of:		7 PM	8	9	10	11	12	1 AM	2	3	4	5	6	7	8
6/24-25	Temp.		85°				75°		67°				66°		
	No. caught	-			307			7			2			0	
6/25-26	Temp.		83°		3/				69°				67°		80°
	No. caught	0		36			37				12			1	
6/26-27	Temp.		78°		75°		72°	72°					65°		
	No. caught	0		0		2	1			0				0	

1/ Based on 10 egg traps hung on tree 45 ft to the ESE of release site.

2/ Sunset occurred at 8:30 p.m. Sunrise occurred at 5:30 a.m.

3/ Temperature not recorded.

Figure 11. Locations of egg traps used to monitor dispersal of Calco oil red-marked female moths, McFarland, Calif., 9/21 to 10/1, 1976.



1/ X designates location of trap.

2/ Release site.

Table VI. September 1976 Dispersal Study. Total number of marked eggs laid during different periods of the night[1] and temperature (°F) at the ends of the periods. McFarland, Calif.

Night of:		Time of Night[2] 6 PM	7	8	9	10	11	12	1 AM	2	3	4	5	6	7	8
9/23-24	Temp.		75°	66°												
	# caught	0	31							0						
9/24-25	Temp.		75°	65°												
	# caught	0	13							0						
9/25-26	Temp.		70°	63°												
	# caught	0	35							0						
9/26-27	Temp.		70°	63°												
	# caught	0	10							0						

1/ All traps were located within 30 ft of release site.

2/ Sunset occurred at ca. 6:40 PM.

continued somewhat longer into the night but ceased at ca. 60°F (Table VII).

The number of marked eggs found during the course of this test was too small to allow us to draw conclusions regarding distances the moths can travel. We can only state that again moth movement was largely into the northeasterly night winds, and that movement away from the release site was slower than it was in June.

Table VII. September 1976 Dispersal Study. Total number of navel orangeworm moths caught in Pherocon 1C™ sticky traps during different periods of the night[1/] and temperature (°F) at the ends of the periods. McFarland, Calif.

Night of:		Time of Night[2/] 6 PM	7	8	9	10	11	12	1 AM	2	3	4	5	6	7	8
9/23-24	Temp.		66°		63°		61°									
	# caught		-	10			8		1			0			1	
9/24-25	Temp.		65°	63°		61°										
	# caught		0	2	1		1			0						
9/25-26	Temp.		63°		61°											
	# caught	0	1	2						0						
9/26-27	Temp.		63°		60°											
	# caught		2	2	1					0						

1/ Based on 10 traps located ca. 2000 ft east of release site.

2/ Sunset occurred at ca. 6:40 PM.

Differential Attractiveness of Infested and Uninfested Almonds to the Navel Orangeworm

K. L. Andrews, L. B. Bjostad, and M. M. Barnes
Department of Entomology
University of California at Riverside

Summary.--Egg traps containing mummy almonds already infested by navel orangeworm larvae received 5-6.5 times as many navel orangeworm eggs as traps containing uninfested almonds. Egg traps containing whole infested almonds received more eggs than traps containing either of the components of infested nuts--1.8 times as many as traps baited with frass and insect parts, and 2.6 times as many as traps baited with "defrassed" nut fragments. Traps containing "defrassed" nut remains received 2.5 times as many eggs as traps with sound nuts.

In another test significantly more navel orangeworm moths (1.8 times) were caught in sticky traps baited with infested than with uninfested mummy almonds. This indicates that the higher number of eggs laid on infested nuts is due, at least in part, to more moths visiting the traps; a volatile attractant present in the infested nuts and frass is either absent or present in lower amounts in the uninfested nuts.

Extracts made of infested nuts, uninfested nuts, frass plus insect parts, and "defrassed" nut parts were put in planchets inside egg traps. All extracts proved to be as attractive as the bran media which is presently used commercially for monitoring navel orangeworm oviposition activity. The extracts, however, did not show the differential attractiveness that their respective solid counterparts did.

Introduction.--Several researchers have recorded that the navel orangeworm, *Paramyelois transitella* (Walker), lays significantly more eggs on already infested walnuts than they do on sound nuts (Proshold 1967, Bruce 1975). Others have reported the same for almonds (Rice--Personal Communication, Curtis 1975) and pistachios (Andrews--unpublished). The results of studies investigating this phenomenon in more detail are reported in this paper. Constituent parts of infested nuts are classified as to their relative attractiveness and consideration is given to the possible nature of the attractant/stimulant(s) involved.

The three experiments reported were conducted in the center of a 500-acre mature almond orchard 10 miles east of Caruthers, Fresno County, California. Fifty per cent of the orchard was planted to 'Nonpareil' variety, 25% to 'Ne Plus' and 25% to 'Milow (1238)'. The orchard was irrigated by solid set, under-tree sprinklers, and was kept weedfree.

The egg traps used were of two kinds: ca. half of the traps were made in our lab according to the specifications of Rice (1976). Each trap was made by cutting two large windows out of a 25-dram clear plastic vial and covering the windows with nylon organdy. The attractant materials are placed within. No attempt was made to smooth the glue used to hold the organdy in place since roughened surfaces seem to be better oviposition sites than smooth ones. The rest of the traps were 'Pherocon IV'™ egg traps., (Zoecon Corp., Palo Alto, CA). These traps were of the same basic structure as the others. Our data (unpublished) from other tests indicate no significant difference in egg laying on traps from the two sources.

Experiment 1

Material and Methods.--To bait the traps, one-year-old mummy almonds were collected and broken open individually. If a nut was free of insect damage in both the hull and nutmeat, it was classified as sound. It was classified as infested if the nutmeat had been damaged by NOW. Nuts which were infested in the hulls only were discarded.

One-third of the opened infested nuts were saved without further modification and one-third was used for extraction as described below. The remaining third was divided into two portions. One portion consisted of all the frass, webbing, pupal cases, and living immature navel orangeworms which could be removed from the uneaten portions of the nut. The other portion, called here "defrassed nuts", consisted of the remaining uneaten nut fragments.

In summary, the four solid baits were: 1) sound whole nuts, 2) infested whole nuts, 3) frass plus insect parts collected from infested nuts, and 4) "defrassed" nut parts produced by removing NOW-produced debris from infested nuts.

A portion of each of the four solid baits had been saved for extraction. These solids were extracted in di-ethyl ether. After reducing the volume of ether by distillation, the high molecular weight compounds were removed from the concentrated extracts by centrifugation. An attempt was then made to remove the last traces of ether by further distillation. A yellowish-brown oil was produced in each case. By extracting five almonds (or frass from 5 nuts) about 3 drops of extract was produced.

Twenty-five traps were filled to the top with sound nuts. This generally took 4-5 nuts. Another 25 were filled completely with infested nuts. The frass plus insect debris which had been collected from a volume of nuts equal to that required to fill the 25 infested nut traps was divided into 25 equal portions. Each portion was then placed in a trap on top of a wad of yellow notebook paper in order to lift the frass to the height of the organdy windows of the egg traps. Thus the amounts of frass found in traps baited with infested nuts and in traps baited with frass only were approximately equal. The defrassed nut debris which remained after cleaning a volume of nuts equal to that required to fill the 25 infested nut traps was divided into 25 equal portions and placed in the traps.

Three drops of the extract from sound nuts were placed into teflon planchets with an inside diameter of 5 mm^2 in each of 25 egg traps. The same thing was done for the other 3 extracts for a total of 100 traps containing extract.

The test was initiated on 29 July 1976. The four solid and the 4 extract treatments were randomized in blocks and replicated 25 times. Egg traps containing the baits were hung, 1/tree, 6-8 feet from the ground in the NE quadrant of the tree and checked daily for eggs for three consecutive days. Since nut dehiscence had not reached a significant point, trees of all three varieties were used.

<u>Results</u>.--Daily egg count totals for each treatment are given in Table I. Extract catches were so low that they were excluded from further analysis. Analysis using Duncan's new multiple range test indicates that traps baited with infested nuts received significantly more eggs than traps containing any of the other baits. Traps containing frass received significantly more eggs than the uninfested nuts did. The difference between the defrassed and sound baits was almost significant (P = .05). Note also that the average number of eggs laid on traps

Table I. Number of navel orangeworm eggs[1] on traps variously baited, Caruthers, California, 1976.

Night of	Infested nut	Frass	Defrassed nut	Sound nut	Frass extract	Infested nut extract	Sound nut extract	Defrassed nut extract
7/29	115	63	64	26	3	5	7	0
7/30	219	111	53	28	4	1	2	3
7/31	149	97	68	17	17	15	5	6
3-night totals	483	271	185	71	24	21	14	9
Mean[2]	6.44	3.61	2.47	0.95	0.32	0.24	0.16	0.12

[1] Total number of navel orangeworm eggs on 25 traps.

[2] Means over the same line are not different (P = .05), by Duncan's New Multiple Range Test, extract data excluded.

containing frass (3.61) plus the average number of eggs laid on traps containing defrassed nut debris (2.47) is almost equal to the number of eggs laid on traps containing infested nuts (6.44). This would suggest an additive effect.

Experiment 2

Material and Methods.--The second test was initiated on August 2 with treatments consisting of empty traps, traps baited with the standard commercial NOW bait, the four solid baits, and the four extracts. Randomized blocks were replicated 13 times. Large aluminum foil planchets with ca. 50X the surface areas of the teflon planchets were used to hold the four extracts. Approximately 12 drops of extract were placed in each planchet. The standard NOW bait was made according to specifications of Rice. The traps were hung in Ne Plus trees in the same manner as in the first test and were checked for eggs after 4 and 8 nights.

Results.--The second test did not reveal anything additional about the activity of the solid baits. If anything, the results for the solid baits (see Table II) are less precise than those of the first test due to the smaller number of replications. Instead, it is the performances of the four liquid extracts which warrant consideration.

The results of the analysis using Duncan's new multiple range test are reported in Table II. The solid baits are ranked in attractiveness just as they were in the first test, although levels of significance have changed. The four extracts are about equally attractive; they received about the same number of eggs as the traps containing the commercially-used media.

Table II. Number of navel orangeworm eggs[1] laid on traps baited with various solids and extracts, Caruthers, California, 1976.

4-night period	Bait: Solid infested nuts	Solid frass	Solid defrassed nuts	Bran media	Frass extract	Defrassed nut extract	Sound nut extract	Infested nut extract	Solid sound nuts	Empty egg traps
8/2-5	131	80	105	68	87	77	59	50	22	0
8/6-9	68	92	62	46	26	16	20	25	12	1
2-period totals	199	172	167	114	113	93	79	75	34	1
$\bar{x}$ [2]	7.65	6.62	6.42	4.38	4.35	3.58	3.04	2.88	1.31	0.04

[1] Total number of navel orangeworm eggs on 13 traps.

[2] Means over the same line are not different (P = .05) by Duncan's New Multiple Range Test.

By increasing the release rate by a factor of ca. 50X, the relative effectiveness of the extracts as compared to the infested nuts was increased by a factor of 10 (see Table III).

Experiment 3

Materials and Methods.--Fifteen randomized blocks were laid out on July 30. Each block contained the following replicates: 1) a Pherocon 1C™ stick trap (Zoecon Corp., Palo Alto, CA.) baited with an egg trap containing infested nuts, 2) a sticky trap baited with an egg trap containing uninfested nuts, and 3) a sticky trap containing an empty egg trap. The traps were hung one per tree. They remained in the orchard until August 9 when they were collected and the number of navel orangeworm moths caught in each was recorded.

Results.--Using the least significant difference test, it was shown that significantly (.05 level) more moths were caught in sticky traps baited with infested nuts than in traps which held uninfested nuts (Table IV). The difference, while it is significant, is not as great as that seen between the number of eggs laid on traps baited with infested vs. uninfested nuts. These results indicate that a volatile acting as an attractant of some sort is present. Whether this attractant is the only factor involved in the phenomenon is not clear; the presence of compounds acting in other ways, say perhaps as oviposition stimulants, is not ruled out.

Conclusions.--The results of these tests demonstrate that a volatile attractant present in the frass of infested nuts (and possibly on the "defrassed" nut debris) is either not present or is present in lower amounts in uninfested nuts.

Table III. Extract performance as a function of release rate, Caruthers, Calif., 1976.

Date	Release substrate	Bait	No. of eggs counted	No. of "Trap-nights"	No. of eggs/trap/night	Ratio of eggs/trap/night for traps w/infested nuts:Eggs/trap/night for extract traps
July 27 to July 31	Teflon planchets (Release area ca. 80 mm^2)	4 extracts	95	500	0.19	23:1
	-	Infested nuts	483	125	3.86	
Aug. 2 to Aug. 9	Aluminum foil planchets (Release area ca. 3800 mm^2)	4 extracts	359	416	0.87	2.2:1
	-	Infested nuts	199	104	1.90	

Table IV. Number of navel orangeworm moths caught in sticky traps containing egg traps baited with either uninfested or infested almonds, Caruthers, Calif., 7/29 to 8/9/76.

Block No.	Infested nuts	Uninfested nuts	Blank
1	3	3	0
2	3	0	0
3	5	2	0
4	2	4	0
5	4	1	0
6	3	4	0
7	4	1	0
8	8	3	0
9	0	2	0
10	6	1	1
11	2	2	0
12	4	2	0
13	4	0	1
14	0	0	0
15	1	3	0
Total	49	28	2
$\bar{x}$	3.3[1/]	1.9	0.1
SE	0.56	0.35	

[1/] Significantly different from 1.9 by least significant difference tests (P = 0.5).

Second, the results allow us to hypothesize "redundant infestation" as a major factor in the plateauing of infestation rates as reported by R. Curtis. The infestation of the new crop seems to begin with the onset of hullsplit. There is likely some "lag period" before nuts containing navel orangeworm larvae become significantly more attractive than uninfested nuts. Once a nut becomes more attractive to moths than its neighbors, it is likely to receive a disproportionate number of new eggs. Since only a finite number of females and eggs can be present in an orchard at any time, any tendency to oviposit on already infested nuts must result in an infestation rate increase which is slower than that expected if egg laying were strictly random. Eventually, the infestation rate will plateau.

It is notable that after one extraction effort and only two tries at a suitable release rate, we obtained extracts which were comparable in attractiveness to the media currently used for monitoring populations of navel orangeworm. Work toward refinement of extraction and release techniques is planned.

Natural Enemies of *Tetranychus* spp. Observed in 1976 in Kern and Tulare Counties

K. L. Andrews and M. M. Barnes
Department of Entomology
University of California at Riverside

Several natural enemies of *Tetranychus* mites were encountered in 1976. These included minute pirate bugs (*Orius tristicolor*), big-eyed bugs (*Geocoris* spp.), damsel bugs (*Nabis* spp.), *Stethorus* beetles (*Stethorus picipes*), syrphid larvae (family Syrphidae), various species of predatory mites (family Phytoseiidae), green lacewing larvae (*Chrysopa carpea*), and sixspotted thrips (*Scolothrips sexmaculatus*). Only the latter 2 insects were ever observed in high enough numbers to be considered important mortality factors.

During the early season green lacewing nymphs were often observed feeding voraciously in mite colonies. The impact they had on mite populations during this time is not known. The numbers of green lacewings declined dramatically in most orchards in June and July and these insects were difficult to find in August and September.

Sixspotted thrips, on the other hand, could be found throughout the year in orchards. Their ability to overtake and suppress exploding *Tetranychus* populations was documented. It was observed that they could control even low early season populations of mites. Their appearance in threatened orchards, however, was sporadic and usually too late to prevent damage to the trees. Studies of the biology and ecology, and the means of manipulating this species are warranted.

Acaricide Performance Trials

K. L. Andrews
Department of Entomology
University of California at Riverside

Three acaricide performance trials were conducted during the summer of 1976. Two of these experiments warrant detailed write-ups while the third will be mentioned only in passing.

In these tests the target species of primary concern was either the Pacific spider mite, Tetranychus pacificus McGregor, or the twospotted spider mite, T. urticae Koch. Whenever the citrus red mite, Panonychus citri (McGregor), was present it was also counted. In addition to counts of mites, the effect of the various chemicals on the sixspotted thrips, Scolothrips sexmaculatus (Pergande) was studied. This insect appears to be the most important predator of spider mite pests of almonds in the southern San Joaquin.

Experiment 1

Effects of Three Acaricides on Tetranychus urticae Koch, Panonychus citri, (McGregor), and Scolothrips sexmaculatus (Pergande). Roberts Farms. Code 194. Richgrove, Calif.

Materials and Methods.--An experiment was conducted in 2 parts of a 130-acre block of 10-year-old almonds, located 2 miles east of Richgrove, Tulare Co., California to compare the effectiveness of Omite 30W, Uniroyal UBI-R677, and Gulf GCP-5126 for control of the twospotted spider mite, Tetranychus urticae Koch, and the citrus red mite, Panonychus citri (McGregor). Trees were planted 97 trees to the acre using a 30 X 30 quincunx design. The experimental layout consisted of 6 randomized blocks containing 4 trees each. Four of these blocks were located near the center of the western edge of the orchard and the remaining 2 were situated at the southeast corner of the orchard. One block in the SE area was composed of 4 Merced variety trees, the other of 4 Nonpareil trees. Three of the blocks on the west side of the orchard consisted of 4 Nonpareil trees each, and the 4th block in this area contained 4 Merced trees.

The treatments compared (Table I) were applied using a handgun at 400 to 450 lb pressure. A high pressure, dense spray was used to cover the tops of the trees, but for those areas from which leaves were to be collected for mite counts, a fine spray was used. By this means a minimum of mite population reduction due to the effects of mechanical removal was to be expected. In either case, the foliage was sprayed to the point of runoff. An average of 10-12 gal/tree was applied.

Ten leaves were collected at random from each of the trees immediately prior to spraying on July 21, and again on July 31, and August 18. The leaves were placed in labelled, dampened bags and kept on ice and under refrigeration until they could be counted (within 24 to 48 hours) under a 10X stereoscope. The numbers of *T. urticae*, *P. citri*, and *Scolothrips sexmaculatus* (Pergande) were recorded.

Results.--Table I presents the mean number of twospotted spider mites for each of the four treatments on the three sampling dates. Analysis of the 10-day count results indicates that Omite and GCP-5126 gave comparable control at the 5% confidence level. The control afforded by the R677 treatment was significantly poorer and obviously would not be commercially acceptable. While counting the GPC-5126-treated leaves, it was noted that almost all the twospotted spider mites present were mature females; apparently immatures were especially susceptible to this

Table I. Acaricide Efficacy Trial. Average number of *Tetranychus urticae* per leaf[1/] for each of 4 treatments at the 3 sample dates. Roberts Farms, Code 194, Richgrove, Calif., 1976.

Treatment	Oz a.i. per 100 gal	Sample: Pretreatment 7/21	10 days 7/31	28 days 8/18
Check	-	83.0[a] [2/]	205.5[a]	49.5[a]
UBI R677 0.5 EC	0.4	75.7[a]	92.2[b]	137.8[b]
Omite 30 W	5.3	71.2[a]	12.9[c]	76.0[a b]
GCP-5126 50W	6.5	71.1[a]	5.4[c]	33.2[a]

[1/] Based on 6 samples of 10 leaves each.

[2/] Means in the same column followed by the same letter are not significantly different at the 5% confidence level as determined by Duncan's New Multiple Range Test.

compound. There seemed to be an unnatural preponderance of adults on the Omite-treated leaves as well, but the imbalance was not as pronounced as with the GCP-5126-treated leaves. No such imbalance was seen on either the R677 or the check leaves.

At 28 days the mite populations on the check trees had declined to about one-fourth their density at 10 days. This may be attributed to the depletion of their food resource; the few leaves remaining on the check trees were very severely scarred. The R677-treated trees were defoliating rapidly. Trees treated with Omite were beginning to show both stippling and some defoliation. GCP-5126-treated trees were still green and retained all their foliage.

The numbers of P. citri were too low to allow us to draw any conclusions about the effectiveness of the compounds on this pest species.

Table II presents the total number of sixspotted thrips found in each sample on the 3 sample dates. The predator density was extremely low at the time the chemicals were applied, so no direct mortality estimates can be made. The numbers of thrips present at 10 days is still very low and it is thus unwise to attach any importance to differences among these numbers. The numbers of thrips present at 28 days seem to reflect prey density fairly closely and for that reason it would be unwise to attribute lower numbers of predators to direct chemical-induced mortality. Note only that at both 10 and 28 days, there were about the same number of thrips on the Omite-treated leaves than on the R677-treated leaves even though prey densities were higher in both cases on the latter. This might indicate some suppression of the thrips by R677. No other natural enemies of spider mites were present in significant numbers.

Table II. Total Number[1] of Scolothrips sexmaculatus (Pergande) Found in Each of 4 Treatments at the 3 Sample Dates. Roberts Farms Code 194 Richgrove, California 1976

Treatment	Sample: Pretreatment 7/21	10 Days 7/31	28 Days 8/18	Totals
Check	2	7	15	24
UBI R677 0.5EC	0	2	38	40
Omite 30W	0	4	39	43
GCP-5126 50 W	0	0	8	8

[1] Based on 6 samples of 10 leaves each

Experiment 2

Effects of Five Acaricides on Tetranychus pacificus McGregor and Scolothrips sexmaculatus (Pergande). Roberts Farms Code 6, McFarland, Calif., 1976.

An experiment was conducted in a small area of a 315-acre block of 9-year-old almonds located 5 miles east of McFarland, Kern Co., to compare the effectiveness of Omite 30W, Plictran 50W, Uniroyal UBI-R677 (.5 lb/gal), Zardex 40W, and Golden Dew Sulphur for control of the Pacific spider mite, Tetranychus pacificus. At the same time, the impact of the various chemicals on the sixspotted thrips, Scolothrips sexmaculatus, was studied. As previously noted, this insect appears to be the most important predator of spider mite pests of almonds in the southern San Joaquin.

Materials and Methods.--Trees in the orchard are planted in a 20 x 20 arrangement. The Nonpareil trees in the test area had a very light crop in 1976. When the test was initiated they were suffering from the heaviest early 1976 Tetranychus spp. attack the author observed in either Kern or Tulare counties. The experiment consisted of single tree replicates in 9 randomized blocks.

The materials (Table III) were applied during the mornings of June 16, 17, and 18, when drift problems were minimal, using hand guns at ca. 400 lb pressure. A high pressure, dense spray was used to cover the trees, spraying to runoff. An average of 11 gal/tree was applied.

Twenty leaves were collected (10 at random from the N side, 10 at random from the S side) from each of the 108 trees immediately prior to the start of spraying on June 16. The leaves were placed in labeled, dampened bags and kept on ice and under refrigeration until they were

Table III. Mean number of *Tetranychus pacificus* per leaf[2] for various treatments at each of 5 dates. Roberts Farms Code 6 McFarland, CA. 1976.

Compound	oz a.i. per 100 gal	Sample: Pretreatment 6/17	10 days 6/27	21 days 7/8	36 days 7/24	52 days 8/10
Plictran 50W	1.8	12.1	0.0[a] [1/]	0.9[a]	12.6[a]	.07
Omite 30W	4	4.9	0.04[a]	.15[a]	4.9[b]	0.1
Omite 30W	2.7	3.4	0.1[a]	.7[a]	4.1[b]	0.1
Zardex 40W	6.4	6.9	0.3[a]	.7[a]	4.3[b]	.05
Zardex 40W	3.2	3.5	1.3[ab]	1.6[a]	2.3[b]	.07
Zardex 40W	1.6	8.1	4.5[bc]	5.1[ab]	1.4[b]	.06
UBl R677 (.5 lb/gal)	0.027	12.0	3.1[bc]	9.4[b]	-	-
UBl R677 (.5 lb/gal)	0.014	11.4	3.9[bc]	-	-	-
UBl R677 (.5 lb/gal)	0.007	8.9	4.6[bc]	-	-	-
Golden Dew	147	6.3	6.0[c]	10.1[b]	-	-
Golden Dew	74	7.3	5.0[c]	8.2[b]	-	-
Check	-	4.7	11.1[d]	17.4[c]	0.6[b]	.08

1/ Means in the same column followed by the same letter are not significantly different at the 5% level by Duncans new multiple range test.

2/Based on 120 leaves on 6/17, 7/24, and 8/10; and 180 leaves on 6/27 and 7/8.

counted using a 10X stereoscope. Counts were completed within 48 h. The numbers of all post-egg stage *T. pacificus* and *S. sexmaculatus* were recorded. An identical sampling and counting procedure was utilized at 10, 21, 36, and 52 days, except that only 6 of the 9 blocks were checked at 36, and 52 days.

Residue samples were collected from 3 of the trees treated with Zardex at 3.2 oz a.i./100 gal. These samples were collected at 0, 1, 3, 6, 10, 14, 21, 28, and 35 days.

Results.--Table III presents the mean number of Pacific spider mites for each of the treatments on each of the 5 sampling dates. Analysis of the 10-day data using Duncan's New Multiple Range Test indicates that Plictran, Omite, and the two highest rates of Zardex gave the best initial control of the pest. The other treatments had variously higher means, all of which were lower than the check trees. The fact that they are lower may be due primarily to the mechanical effects of the high volume, high pressure application procedure itself. In a study not reported here it was shown that the application of a high volume of water under high pressure resulted in a 50% reduction of the mite population, probably by drowning of mites, by washing large numbers of them off the leaves, and by knocking the most heavily colonized leaves off. A reduction by ca. half may be seen for the R677, the Golden Dew, and the low Zardex treatments; no activity of these compounds at these rates is indicated. Because of a misunderstanding, the R677 was applied at rates which were only about 1/20 those suggested by the manufacturer. For this reason monitoring of these trees was discontinued.

The 21-day counts revealed essentially the same set of relationships as were found at 10 days. Some resurgence of the mite populations was evident for all treatments.

By 36 days the ranking of the means had almost exactly reversed itself. That is, those trees which had previously shown the lowest number of mites now had the highest and those which had been most severely infested were now relatively free of mites. The Plictran-treated trees had the highest mean number of mites and the check trees had less than half the number of any other treatment.

At 52 days all the populations had crashed. Since the foliage appeared to be healthy and suitable and no other condition, such as cultural practices or the application of chemicals, could be used to explain the 36- and 52-day counts, we must look to natural enemies as a possible explanation. Only Scolothrips sexmaculatus was encountered in any significant numbers in this orchard during the course of this test. A comparison of Tables III and IV will reveal several things: 1) S. sexmaculatus appeared too late in this orchard for us to be able to say anything more quantitative than that at 10 days S. sexmaculatus density appears to be very closely related to prey density. Thus, any comparison of the toxicity of the chemicals to S. sexmaculatus is not possible, 2) high mite densities at 36 days were associated with low S. sexmaculatus counts on the two previous sample dates, 3) low mite densities at 36 days were associated with high S. sexmaculatus counts on the two previous sample dates, 4) the low mite densities observed at 52 days were preceded by high S. sexmaculatus densities at 36 days. While the latter 3 associations do not prove that S. sexmaculatus was the agent which suppressed the mite buildup, they make a strong case for this hypothesis.

Table IV. Mean number of Scolothrips sexmaculatus per leaf 1/ for various treatments at each of 5 dates. Roberts Farms Code 6 McFarland, CA. 1976

Compound	oz a.i. per 100 gal	Sample: Pretreatment 6/17	10 days 6/27	21 days 7/8	36 days 7/24	52 days 8/10
Plictran 50W	1.8	0	0	0.01	0.23	0.20
Omite 30W	4	0	0.02	0.01	0.07	0.02
Omite 30W	2.7	0	0.01	0.01	0.1	0.12
Zardex 40W	6.4	0	0	0	0.15	0.10
Zardex 40W	3.2	0	0.01	0.01	0.17	0.05
Zardex 40W	1.6	0	0.08	0.03	0.28	0.07
UBl R677 (.5 lb/gal)	0.027	0	0.18	0.03	-	-
UBl R677 (.5 lb/gal)	0.014	0	0.20	-	-	-
UBl R677 (.5 lb/gal)	0.007	0	0.22	-	-	-
Golden Dew	147	0	0.09	0.01	-	-
Golden Dew	74	0	0.09	0.08	-	-
Check	-	0	0.24	0.11	0.53	0.02

1/ Based on 180 leaves for first 3 dates & 120 leaves at 36 and 52 days.

Diurnal Resting Sites of the Navel Orangeworm

Lodewyk P.S. Kuenen
Department of Entomology
University of California, Riverside

Materials and Methods.--These observations were conducted in a 130-acre almond orchard in Tulare County. At 5 a.m., before dawn, on September 3, 1976, 2600 NOW adults were released from ground level at one point in this orchard. The weather was cool, about 70°F, with a nearly full moon and a light overcast of clouds. During the ensuing day cloudiness increased to complete overcast and the temperature rose to 93°F but dropped to about 80°F by the end of the dirunal observation period.

The moths were collected the night of September 2 from a greenhouse rearing cage. These moths emerged from field collected almonds. The moths were stored 200/1-gal ice cream container at 60°F until 4 a.m. September 3, one hour before release. Storage at this lowered temperature was employed to slow moth activity and thus minimize damage that could arise from their confinement in the containers. Prior to collecting the moths, it was observed that new moths were emerging daily in the rearing cage, so the age structure of the collected moths could not be determined.

The moths were observed for 30 min after the release to follow their flight and landing behavior. From 4 p.m. until 7:30 p.m. of the same day, 3 trees immediately adjacent to the release point were examined for presence of NOW adults (Fig. 1). The trees were divided into search areas on the basis of height, 0 to 6, 6 to 8, 8 to 10, and above 10 ft. The following locations were also classified: nut (any part), leaf

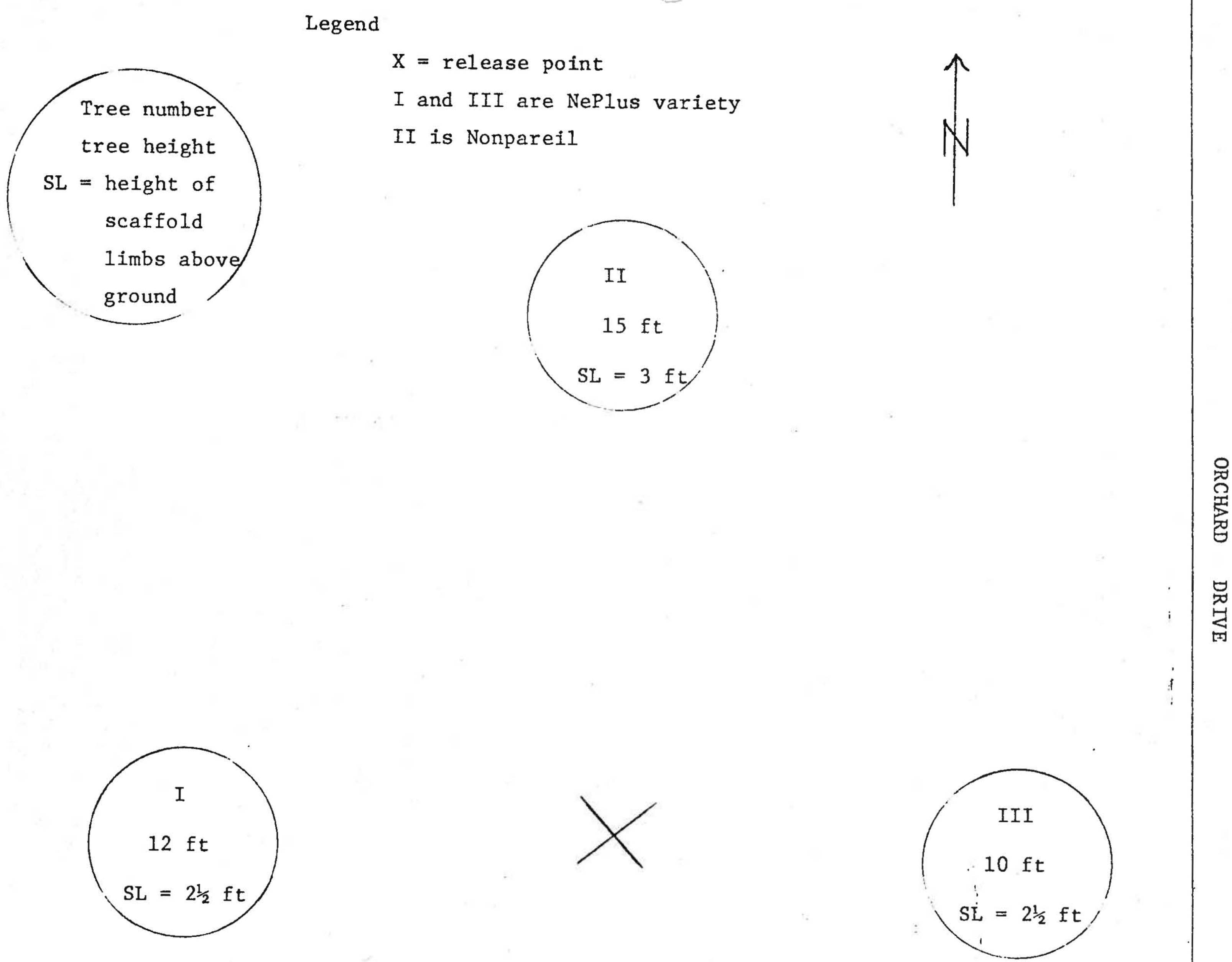


Fig. 1. Navel orangeworm orchard release site.

(and petiole), twigs interior and twigs exterior, larger branches (diameter greater than or equal to ½ in.), and the trunk.

In this orchard the Nonpareil variety of almonds had already been harvested but pollinators had not. The resulting variability of tree foliage and nut presence or absence as well as different tree sizes prevented the standardization of the searching process in terms of time spent examining various surfaces, i.e. equal opportunity of moth detection on each surface. At elevations above 6 ft a ladder was used so that all tree parts could be seen equally. The ground was examined for NOW at first visually and then by vigorous disruption of the leaf litter to attempt to incite moth flight.

Results and Discussion.--Shortly after opening the containers the moths began to emerge from them and flew toward the upper tree portions in all compass directions. No consistent behavior pattern was discernable at this time. Some moths flew directly out of sight, some alighted momentarily on a tree and then flew off again, and still others alighted on trees and stayed there throughout the initial observation period. Of the moths observed at this time most flew quickly to elevations above 6 ft.

Table 1 shows the tree areas examined in the late afternoon and the number of adult NOW's found in these areas. To determine if a random distribution was represented by these numbers, Chi-square tests were performed for tree height areas and for substrates. These tests showed that the data was not randomly distributed (P = .005). No moths were observed resting on the ground nor on anything on the ground such as leaf litter, mature almonds, or trash.

Table I. Diurnal Resting Sites of Adult Navel Orangeworms on Almond Trees

Height of search areas	Substrate on which moths were found: Nuts			Leaves			Interior twigs[1/]			Exterior twigs[2/]			Limbs[3/]			Trunk			Totals[4/]
0 to 6 ft	2	-	3	1	1	1	3	4	6	0	3	2	0	0	3	0	1	1	31
6 to 8 ft	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	4
8 to 10 ft.	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
>10 ft	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3
Tree No.	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	
Subtotals	6	0	3	2	1	2	6	4	7	0	3	2	0	0	3	0	1	1	41*
Totals		9			5			17			5			3			2		

1/ Twigs are less than ½ in. in diameter. Interior is any point less than ½ the distance from the center of the tree to the edge of the canopy.

2/ Twigs are less than ½ in. in diameter. Exterior is any point more than ½ the distance from the center of the tree to the edge of the canopy.

3/ Limbs are branches having a diameter of more than ½ in.

4/ Trees I and III were NePlus, II, Nonpareil.

* Total number of adult navel orangeworms found.

Moths that were observed during the diurnal search period showed no special orientation except for those found on interior twigs. These moths were mostly found to be perched on small first-year growth twigs and aligned longitudinally with them. Aligned in this manner the wings were wrapped around the twig and the cryptic coloration of the moth was in evidence. Additionally, the "square-shouldered" shape of the moths causes them to resemble small broken twigs.

In summary, during the late afternoon most moths were found in the interior of the tree and below 6 ft.

The Relationship of Nonpareil Almond Hullcrack and the Development of the Infestation by Navel Orangeworm

Lodewyk P.S. Kuenen
Department of Entomology
University of California, Riverside

The navel orangeworm is the key pest of soft shell almonds in the southern San Joaquin Valley. Learning more about the biology and infestation cycle of this pyralid moth may well lead to better control measures. It is in light of this that a study was undertaken on the seasonal development of the nut crop and the onset and seasonal progression of nutmeat infestation in Nonpareil almonds in 1976.

Materials and Methods.--This study was conducted in a 500-acre almond orchard near Caruthers, Fresno County, Calif. This orchard was planted with 50% Nonpareil, 25% NePlus, and 25% Milow (1238) varieties. Fifty acres in the southwest corner of this block received no insecticidal treatments for control of NOW, but instead were cleaned of mummy almonds by mechanical shakers during the preceding winter. These mummy almonds were then disced into the soil.

In the middle of this cultural control block, 20 rows of Nonpareil (approx. 20 acres) were established as the sampling area. Each Nonpareil row contained 54 trees. The 2 trees on each end were used as buffer trees, thus yielding a 1000-tree sampling block (with the alternating rows of pollinators interspersed). The Nonpareil trees were consecutively numbered, 1 to 1000, and of these 50 were selected at random for sampling. At each sampling date 20 nuts were chosen from each tree from below the 7-ft level. The nuts were chosen randomly at 5 nuts per tree quadrant. Thus, a 1000-nut sample was taken at each sampling. The nuts were sampled twice per week, beginning July 20, 1976 through September 18.

Within 24 h after the samples were collected the nuts were examined for hullcrack. Hullcrack was considered to exist when the hull showed any separation of the hull along the suture line. These nuts were stored separately and the quantity recorded. The nuts were then stored at ambient field temperatures for 3 to 4 weeks after which time they were stored at 40°F until they were checked for infestation.

The nutmeats were examined for NOW damage from 10/21 to 10/29. Five hundred nuts were examined from various field sampling dates. Nutmeats of hullcracked and non-hullcracked almonds were examined for infestation separately.

Results and Discussion.--The percentage of hullcrack at each sample date was calculated (see Table I and Fig. 1). The percent infestation was calculated and the percent of the hullcracked nuts that were infested. These quantities are shown in Table I and Fig. 1. As seen in

Table I

Seasonal Development of Nonpareil hull-crack and NOW nutmeat infestation

Date	% hull-crack	%infestation 500 nut sample	%infestation of hull-cracked nuts
7/20	0.0	-	-
7/22	1.6	-	-
7/27	1.2	-	-
7/30	4.0	0	0
8/4	12.0	.4	3.3
8/6	17.2	-	-
8/10	32.0	.8	2.5
8/13	28.8	-	-
8/17	49.0	1.6	2.4
8/20	59.8	-	-
8/24	68.2	4.0	5.0
8/27	80.0	-	-
8/31	86.6	8.6	9.9
9/3	94.4	9.6	10.2
9/8	97.4	8.0	8.2
9/11	98.4	18.4	18.7
9/13	99.5	14.2	14.3
9/18	99.9	14.8	14.8

Figure 1

Seasonal Development of Nonpareil Hull-crack and NOW Nutmeat Infestation

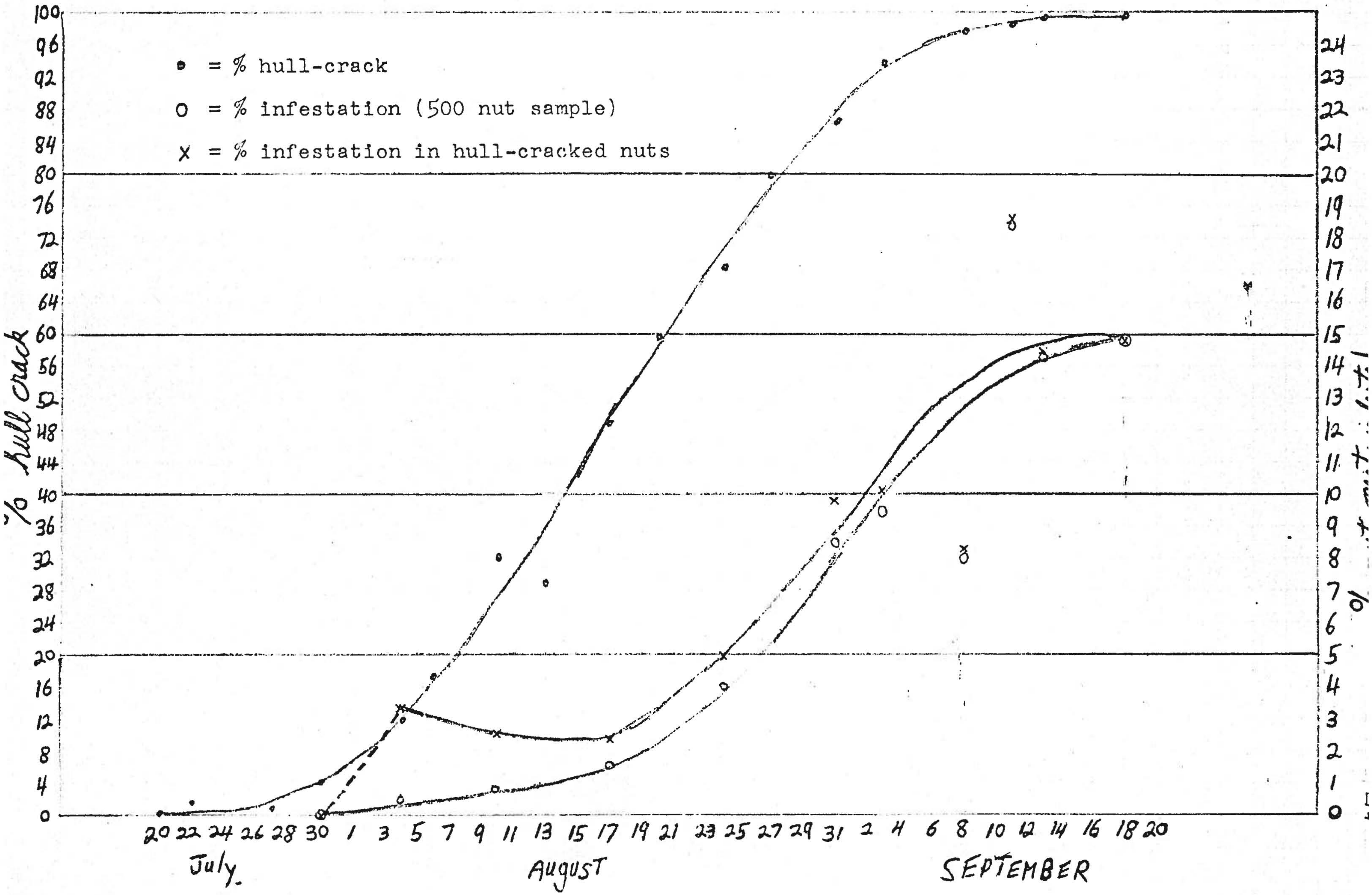


Fig. 1 the progression of hullcrack of Nonpareil almonds exhibits a sigmoid curve. The infestation curves also are sigmoid in character. Except for two apparently aberrant values found on 9/8 and 9/10 attributable to sampling variation, the infestation levels appear to progress at a smooth rate. Yet early in the hullcrack period (8/4 to 8/20) the two infestation curves appear to be divergent. It may be that the few oviposition sites available early in August were readily infested. As the oviposition sites available for the successful invasion of nutmeats increased as August progressed (more hullcracked almonds), a smaller percentage was attacked because of low moth densities. Additionally, Curtis (1976) indicated that oviposition occurs preferentially on already infested almonds. This could further inhibit increase of nutmeat infestation. Curtis (1976) also indicated that the establishment of NOW in nutmeats was inhibited as the shell dried. This may account for leveling off of infestation levels as September progressed, since fewer freshly hullcracked almonds were present at this later time. At 100% hullcrack no fresh sites are available so that infestation increase basically stops.

In this experiment it was found that molds growing on stored nuts often lead to difficulty in ascertaining what, if any, organisms were present in the nutmeats, and may have given rise to some of the variability in infestation values. Earlier examination of nuts after incubation should be employed to avoid this problem.

This area was sampled independently by Rice (Personal Communication) on September 15, 1976. They found a NOW infestation rate of 12.8%. This is not greatly different from this study's 14.8% final infestation count.