Project No. 80-E7
(Continuation of Project No. 79-E6)

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Project: Navel Orangeworm Research
Insecticides and Mite Studies

Objectives: To develop optimum use of insecticides for the control of navel orangeworm in almond orchards, with concomitant research on (1) the development of n.o.w. in physiological time for more accurate timing of insecticide use; (2) efficient use of miticides including screening of new materials and; (3) a study of physiological and growth yield effects of mites on almonds (the latter funded by a USDA/SEA competitive grant).

Progress: Experimental work with the pyrethroid insecticide permethrin (Ambush) has resulted in a decision by Imperial Chemical Industries, U.S., to provide support data for a Section 18 for this compound for use against n.o.w. on almonds. Further work will be carried out with materials not so far advanced.

The Shell chemical pyrethroid, Pydrin, continues to provide better residual control and the company shows interest in registering its use on almonds.

Plans: Work will proceed with heat summation studies on development of n.o.w. in connection with the population dynamics model. Studies with acaracides will be carried out. The correlating work under the USDA grant (see above) will continue.

Almond Industry Participation $15,000

INVESTIGATIONS ON CONTROL OF THE NAVEL ORANGEWORM AND MITES ON ALMONDS - 1980

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TABLE OF CONTENTS

Navel orangeworm on almonds

Summary of results with insecticides over five years

M. M. Barnes and E. F. Laird

Results at hullsplit.--Infestation by navel orangeworm is quite variable from tree to tree. Even when 10 replications of single tree plots are used, which has been our custom, variability often interferes with clear differentiation of treatments in a given trial. A comparison of average results of several seasons with various reasonably effective insecticides from a single application at hullsplit is shown below. These data do not reflect possible effects on the moth stage nor the potential of multiple applications.

Table 1. Larvicidal control, applied at hullsplit. 1976-1980

Trade name	Insecticide	Lb/Acre active ingredient	No. of trials	% control as compared w/untreated
Ambush	permethrin	0.2	4	57
Pounce	permethrin	0.2	2	49
Guthion	azinphosmethyl	2 (50 days before harvest)	3	51
Imidan	phosmet	4	4	46
Larvin	dicarbasulf	2	2	58
Lorsban	chlorpyrifos	4 2	2 1	55 25
Orthene	acephate	4	2	51
Pydrin	fenvalerate	0.2	4	62
Sevin	carbaryl	5	5	32

Insecticide Performance - 1980

Trial for the Control of Navel Orangeworm on Almonds at Hullsplit

C. E. Engle, M. M. Barnes and E. F. Laird

An experiment was conducted on a portion of a Superior Farms orchard, Kern Co., to compare larvicidal efficacy of several insecticides for controlling the navel orangeworm on almonds.

Methods and Materials

The experimental block consisted of flood-irrigated 11-year-old trees. The trees were planted in a 25 X 25-ft planting with alternating double rows of the Nonpareil variety to a single row of the Saurett variety. The experimental design consisted of 17 treatments and 1 check, each replicated 10 times in randomized blocks, with single trees serving as the replicated units. Only Nonpareil trees were used. Treatments (Table 1) were applied using a handgun with a pressure of 400 pounds, providing full coverage; check trees received water only.

At harvest all nuts were shaken from each tree onto canvas tarps; the nuts were then sampled, placed in mesh bags, and refrigerated at 40° F until examined. Infestation was tabulated based on a 300-nut sample per tree, totaling 3000 nuts per experimental treatment.

Results

Table 1 presents average percent of infested almonds per treatment. This experiment compares larvicidal action only in thorough coverage sprays.

When applied in one application at 5% hullsplit, permethrin (Ambush and Pounce) performed as well at 0.2 lb active ingredient/acre as at 0.4

Table 1.--Results of replicated experiment on control of navel orangeworm with full coverage sprays,[a/] Nonpareil variety, McFarland, 1980.

Treatment		Formulation	Lb AI/A	Application date[b/]			Avg. % infested at harvest[c/]	Average % control
				6-27	7-16	8-11		
1.	Pounce	3.2 EC	0.4	-	X	X	2.6 a	69
2.	Larvin	4.18 S	2.0	-	X	-	3.0 ab	65
3.	Ambush	2.0 EC	0.4	-	X	X	3.3 ab	61
4.	Guthion	50 WP	2.0	-	X	-	3.5 ab	59
5.	Ambush	2.0 EC	0.2	-	X	-	4.1 ab	52
6.	Guthion	50 WP	2.0	X	-	-	4.2 abc	51
7.	Pounce	3.2 EC	0.4	-	X	-	4.4 abc	48
8.	Orthene	75 S	4.0	-	X	-	4.6 abc	46
9.	Pydrin	2.4 EC	0.2	-	X	-	4.6 abc	46
10.	Payoff	2.5 EC	0.1	-	X	-	4.8 abc	44
11.	Ambush	2.0 EC	0.4	-	X	-	5.1 bc	40
12.	Mavrik	2.0 EC	0.2	-	X	-	5.1 bc	40
13.	Pounce	3.2 EC	0.2	-	X	-	5.2 bc	39
14.	Imidan	50 WP	4.0	-	X	-	5.3 bc	38
15.	Ambush	2.0 EC	0.2	-	-	X	6.6 cd	22
16.	Sevin/Coax[d/]	80 S	5.0	-	X	-	7.7 d	10
17.	Sevin	80 S	5.0	-	X	-	7.9 d	7
18.	Check						8.5 d	--

[a/]Application by handgun at 1600 gal/acre in 10 replicated blocks of single tree plots.

[b/]7-16 = 5% hullsplit, 8-11 = 90-100% hullsplit.

[c/]Average of 10 samples, 300 nuts each, harvest 8-27-80, treatment means in the same column followed by the same letter are not significantly different at the 95% confidence level.

[d/]Coax applied at 5.5 lb AI/acre.

lb/acre. It took two applications at 0.4 lb/acre, one at hullsplit and one 26 days later, to be discriminated as better than one application at 0.2 lb/acre. However, the timing of the 2nd application was delayed beyond the optimum time (see treatment 15) because of irrigation. Given the fact that in large plots moth kill may be expected with permethrin, these results suggest that in speed sprayer treatments, applications of 0.2 lb active ingredient/acre would merit trial at initiation of hullsplit. In comparisons with and without a 2nd post-hullsplit treatment, the second treatment at the same rate should follow at 15-18 days, rather than 26 days as in this trial.

Other pyrethroids, Pydrin and Mavrik at 0.2 lb active ingredient/acre and Payoff at 0.1 lb, Larvin, a carbamate, and Guthion - each at 2 lb/acre, and Imidan at 4 lb/acre, all gave control which was not different statistically from a single treatment of permethrin in this trial.

Sevin failed to control adequately and the addition of Coax did not improve results.

Use of Guthion for Control of Navel Orangeworm

C. E. Engle and M. M. Barnes

A replicated large block experiment was performed in a Superior Farms orchard to evaluate the efficacy of differing spray schedules based on Guthion 50W for the control of navel orangeworm on almonds. The efficacy of air vs ground equipment for insecticide application was also evaluated. This experiment is a continuation of a series of large block experiments performed with Guthion. Data from all prior and present experiments was examined for efficacy in relation to timing and % control of N.O.W.

The experimental design (Fig. 1) consisted of 5 treatments and 1 check, replicated 3 times in randomized blocks, with at least 25 acres serving as a replicated treated unit. Checks consisted of 1-acre units. The experimental orchard consisted of sprinkler irrigated 12-year-old trees. The trees were planted in a 25X25 ft planting with alternating double rows of the Nonpareil variety to a single alternating row of Mission or Merced.

At harvest, samples were taken from each of 15 trees in the center of each block. Results at harvest (Table 1) indicate no statistical difference at the 95% confidence interval amongst the treated blocks. In previous seasons' experiments, the 45-day interval before harvest has consistently performed better than the single application in May. This is further evidence of increased infestation occurring because of a delayed harvest. This was the case with 58-day preharvest interval in this trial.

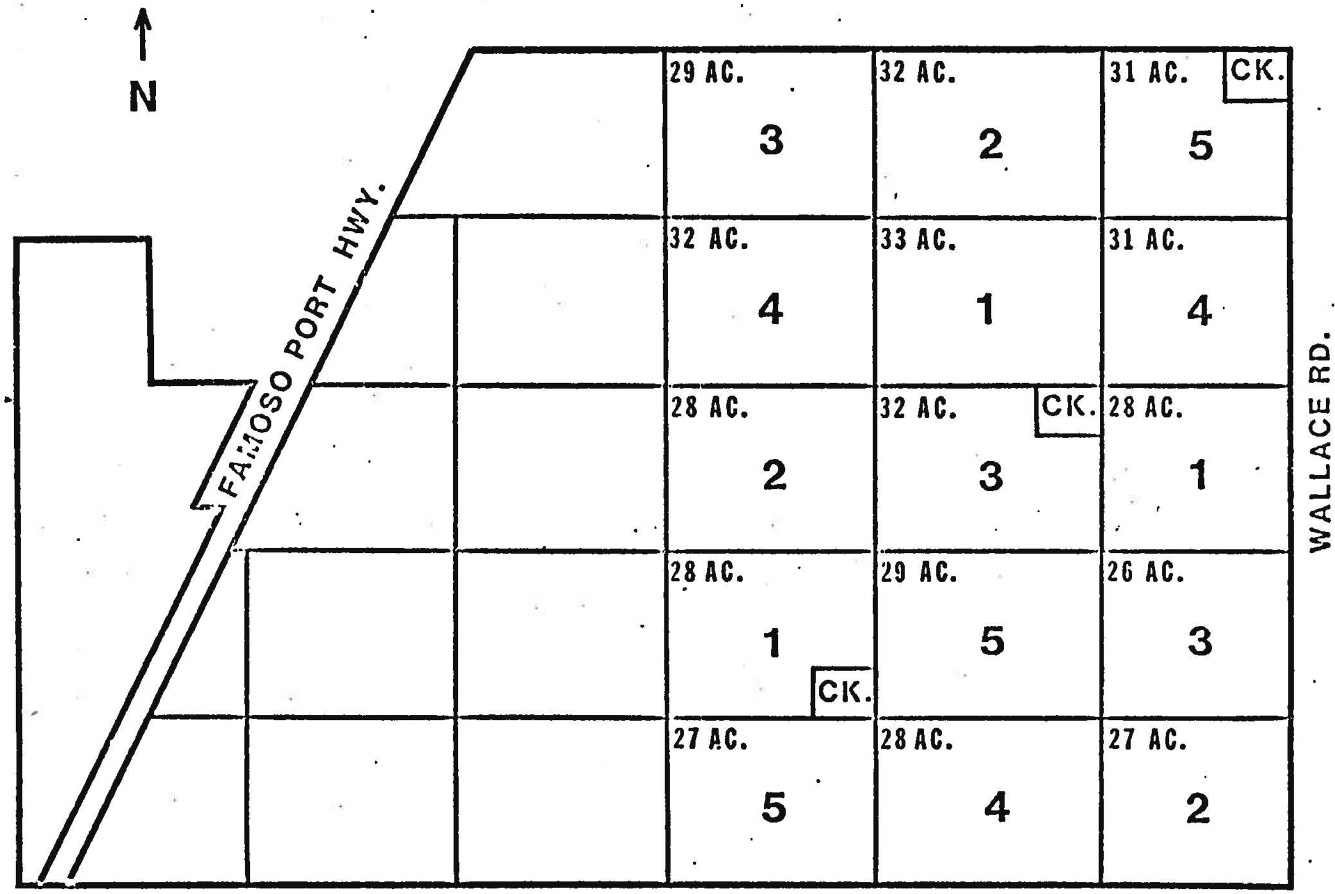

Fig. 1.--Plot layout of treatments in Table 1.

Table 1.--Comparison of oviposition trap timed applications of Guthion for control of navel orangeworm, infesting Nonpareil, McFarland 1980.

Applications	Method of Application	Rate[1/] AI/Acre (lb)	Schedule[2/] April 25	May 9	May 15	June 28	% Infested kernels at harvest[4/]	
1. Guthion 50W	Ground	2.0	X	-	X	-	10.9[6/]	A
2. Guthion 50W	Air	2.0[3/]	X	-	X	-	12.8	A
3. Guthion 50W	Ground	2.0	-	X	-	-	10.6	A
4. Guthion 50W	Ground	2.0	-	X	-	X	10.3	A
5. Guthion 50W	Ground	2.0	-	-	-	X	12.4	A
6. Check[5/]	-	-	-	-	-	-	19.4	B

1/ Three replicates of at least 25 acres each, applications by airblast sprayer in 450 gal/acre.

2/ All treatments received Omite 30W application.

3/ Application by helicopter at 25 mph in 35-40 gal/acre.

4/ Harvested 8-25-80. Average of 15 samples per replicate; 200 nuts taken at random from each tree, totaling 3000 nuts per replicate.

5/ Checks - 3 replicates of 1 acre each.

6/ Means in the same column followed by the same letter are not significantly different at the 95% confidence level.

In summary, the preharvest interval following late season use of Guthion should be not more than 45 days after treatment (the legal restriction at present), i.e. harvest by the spray schedule rather than spraying by a projected harvest date. If Guthion is used in spring, treatment should occur at peak egg laying (Fig. 2). Double applications with Guthion did not significantly improve results at harvest and were not necessary under the existing conditions. Two air applications when compared to two ground applications showed no significant differences at harvest; however, single applications by air craft were not examined.

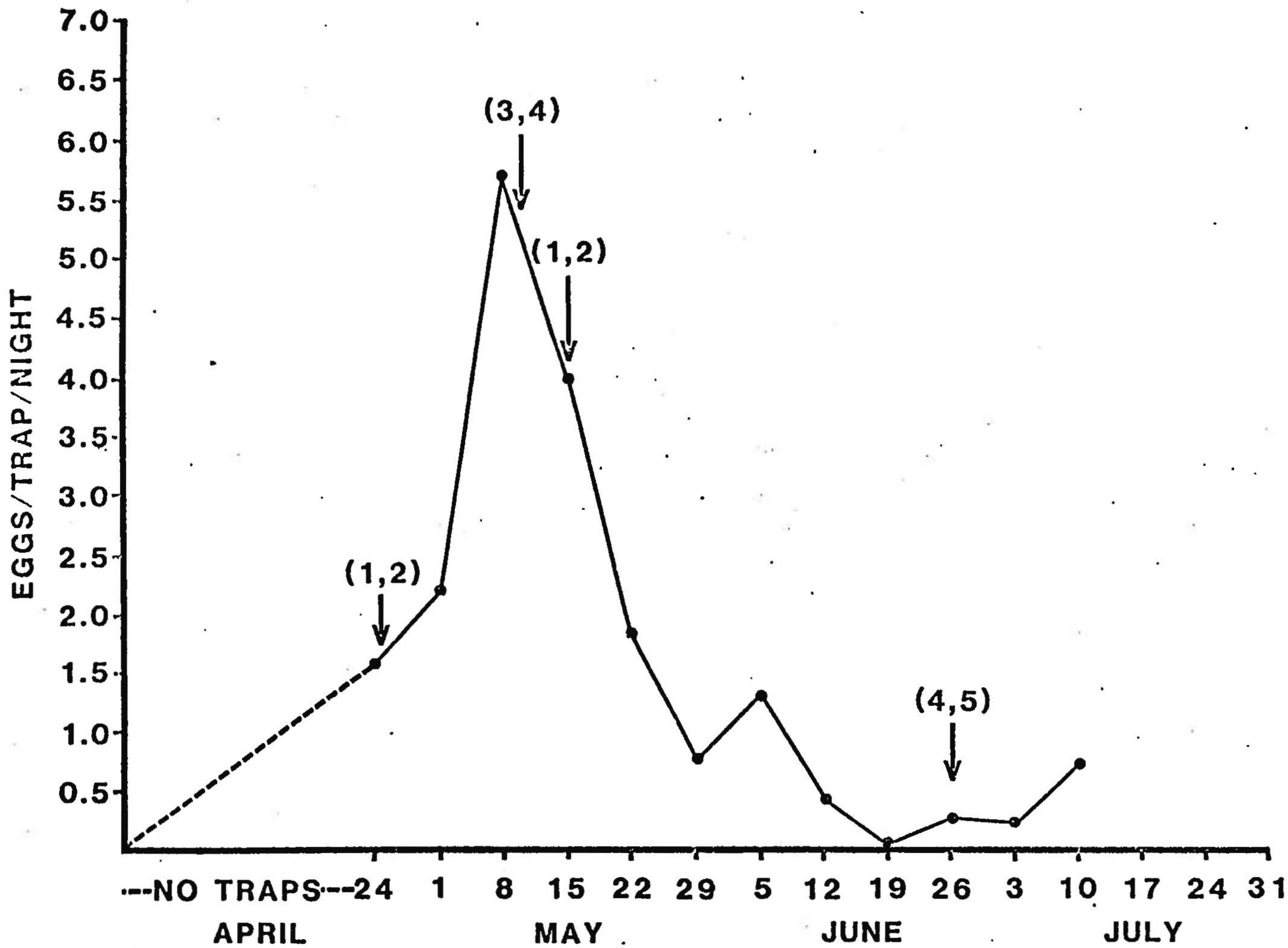

Fig. 2.--Oviposition trap curve in relation to sequence of Guthion treatments.

Evaluation of Navel orangeworm Control with a Guthion Application to Mid-to-Late Harvested Varieties at the 45-day Preharvest Interval for Nonpareil

S. C. Welter and M. M. Barnes

Research to evaluate the efficacy of applying Guthion 50W to mid-to-late harvested pollinator varieties at the 45-day preharvest interval for Nonpareil was continued in 1980. Current pest management practices may include an application of Guthion to the entire orchard at 45 days prior to Nonpareil harvest. Therefore, the timing of this application is based upon the stage of maturation of the variety Nonpareil. Shortly thereafter, the hulls of the Nonpareil variety split open and render the nut susceptible to navel orangeworm attack. In contrast, the mid-to-late harvested varieties will remain unsplit for up to several weeks after the Nonpareil variety has initiated hullsplit. The rationale of this experiment suggested that the navel orangeworm infestations in the mid-to-late harvested varieties would be equal in comparisons between Guthion-sprayed and non-sprayed trees. The unsprayed pollinator varieties are not susceptible to navel orangeworm infestation for several additional weeks after the Nonpareil variety because of the pollinator varieties' later hullsplit. The residue from the Guthion application would have to continue to give adequate control for several weeks longer on the pollinator varieties in order to provide comparable periods of control.

The elimination of the Guthion application to the mid-to-late harvested varieties may also prove less harmful to the natural enemies of spider mites. The native predatory mite, as well as other beneficial predators such as the green lacewings, may be allowed to develop unhampered by an insecticide.

Materials and Methods

Eighteen pairs of the variety Sauret II were established in 1980 within an 11-year-old orchard located approximately 7 mi. north of Shafter, CA. On June 27, Guthion 50W was applied to one tree within each pair at 1.5 lb ai/acre. Approximately 8 gal of formulated spray were applied to each tree with a high pressure hand gun at 450 psi. The other tree in each pair was left unsprayed.

On June 27 the percent hullsplit within the Sauret II variety was estimated as 0% through visual examination. On Aug. 13 the percent hullsplit within the Sauret II variety was estimated as 22% based upon 100 nuts randomly selected throughout the row.

Because the initial emphasis of this project involved evaluation of the Guthion application for navel orangeworm control, the mite populations were controlled with an application of Omite 6E at 3 lb ai/acre on July 10. The mite populations continued to remain at levels too low for any meaningful comparisons to be made between the Guthion sprayed and unsprayed trees.

Infestations of navel orangeworm were estimated through examination of 300 nuts per tree. Samples were taken on Sept. 13 which coincided with the commercial harvest of the orchard. The samples were stored at 4.4°C until the nuts were hand cracked and examined for percent infestation of the nutmeats.

Results

The unsprayed trees showed a mean infestation rate of 8.5%, while the trees sprayed with Guthion showed a mean infestation rate of 6.9%. This 1.6% difference, however, was not statistically significant. (Table 1)

Table 1.--Efficacy of Guthion 50W applications at the 45-day-preharvest interval for navel orangeworm control on mid-to-late harvested varieties.

Treatment	Date applied	Formu-lation	Rate	Gal H_2O per acre	Percent infestation N.O.W.[1/]
Guthion	June 27'80	50W	1.5 lb ai/A	560	6.9 N.S.[2/]
Unsprayed	-	-	-	-	8.5 N.S.

[1/]Based on a mean of 18 trees at 300 nuts/tree.

[2/]Means followed by "N.S." are not statistically different using a paired t-test.

Based upon this data, an application of Guthion to the Sauret II variety did not appear to significantly reduce the navel orangeworm infestation compared to the unsprayed trees. If this relationship is consistent for all mid-to-late harvested varieties, then varieties such as Carmel, Merced, Thompson and Mission will also be unaffected by a Guthion spray at the 45-day preharvest interval for Nonpareil. Thus, it would appear that the Guthion residue did not last long enough to provide effective residual control for the mid-to-late harvested varieties.

If the elimination of the Guthion spray to the mid-late harvested pollinator varieties proves economically effectual after further testing, then 16-50% of an orchard may be left unsprayed depending upon the orchard's pollinator planting scheme.

If the cost of the insecticide is assumed to be $13/acre, then a range of $215-$650 could be saved for a 100-acre orchard, depending upon its particular planting.

In addition to the reduced insecticide output, the unsprayed rows would allow for the conservation of natural enemies, parasites or predators. Because of the continued low levels of spider mites within the orchard, the results of leaving a source of predatory phytoseiid mites within an orchard for spider mite control has yet to be examined.

The results of this experiment look promising, but will have to be tested on a larger scale in 1981 using a commercial application. The effects of the elimination of an application of Guthion on the mid-to-late harvested varieties will then be evaluated as a potential pest management tool.

Late Season Control for Navel Orangeworm and Mites Infesting Merceds and Nonpareils by Ground and Air Applications

R. R. Youngman and M. M. Barnes

A commercial application for navel orangeworm control was performed on late-harvested Nonpareils and late-maturing Merceds using permethrin (Ambush and Pounce). This was possible due to the Section 18 granted for emergency use of permethrin on almonds by the Environmental Protection Agency. The Merced variety matures much later than the Nonpareils and is generally harvested after the Nonpareil harvest. It is during this preharvest interval that the Merced variety experiences heavy navel orangeworm pressure from the populations sustained on the Nonpareils.

The experiment attempted to obtain information about the efficacy of permethrin in reducing navel orangeworm infestation in both the Merced and Nonpareil varieties. An analysis of variance was used to compare percent infestation of treated to untreated checks. A statistical analysis took into account interaction among treatments, rows and treatment-row effects. This was tested at a 19:1 significance level.

Both varieties examined were treated in one orchard by a speed sprayer and in the second orchard by helicopter. All treated trees received a commercial application of Plictran 50W. Mite damage assessments were made between untreated trees and those treated with permethrin plus Plictran.

Materials and Methods

Experiment I. Speed Sprayer Application

The fifteen-year-old orchard is located near the east side of

Hwy. 99 and south of Phillips Road in Kern Co., indicated in Table 1 as 11A. Trees were planted on a 25X25 foot spacing and were flood-irrigated. The planting ratio of Merceds to Nonpareils to Texas Missions is 1:1:1, respectively.

Six rows were selected for treatment with three rows on either side of the center of the orchard. One-half of the entire orchard was sprayed with Ambush, the other half with Pounce. Each row was divided into eleven blocks; each block consisted of 5 trees. Two blocks were randomly picked, one chosen to be the treated block and the other was left as the untreated check.

Experiment II. Helicopter Application

The fifteen-year-old orchard is located on the west side of Hwy. 99 immediately north of Hwy. 46 in Kern Co. The treatments of Ambush and Pounce in Table 2 are indicated as 14H and 14G, respectively. Trees were planted on a 25X25 foot spacing and were flood-irrigated. The planting ratio of Merceds to Nonpareils to Texas Missions was 1:2:1, respectively.

Four rows were randomly selected in each orchard; two for the treatment and two for the untreated check. Each row was either completely sprayed or unsprayed depending upon the treatment. In each of the four rows, five trees were randomly selected to be sampled. Enough space was left on either side of the untreated check to avoid drift.

Results and Discussion

Table 1 presents the average percent infestation of treated and nontreated trees utilizing a commercial speed sprayer ground application. In all but one comparison there is a slight trend towards reduction of

Table 1. Late Season Ground Application of Permethrin for Control of NOW.

Variety	Orchard	Treatment	Lb a.i.[1/] per acre	Gal H_2O per acre	Trt date	Avg. %[2/] infes- tation	Harvest date
Merced	11A	Ambush	0.2	400	8/28	20 NS[3/]	10/11
		Check	--	--	--	33 NS[3/]	10/11
Merced	11A	Pounce	0.2	400	8/29	29 NS[3/]	10/11
		Check	--	--	--	34 NS[3/]	10/11
Nonpareil	11A	Ambush	0.2	400	8/28	24 NS[3/]	9/23
		Check	--	--	--	21 NS[3/]	9/23
Nonpareil	11A	Pounce	0.2	400	8/29	19[4/]	9/23
		Check	--	--	--	26 NS[3/]	9/23

[1/] Includes Plictran 50W, 1 lb a.i. per acre and ZNP, 1 quart per acre.

[2/] Based on 4500-nut sample per treatment.

[3/] NS indicates no significant differences at 19:1 odds.

[4/] Significant at 19:1 odds.

infestation using Ambush or Pounce. One comparison within the Pounce treated Nonpareil variety demonstrated significant reductions of NOW infestation at the 95% confidence level.

Table 2 also presents the average percent infestation of treated and nontreated trees utilizing an air treatment. No significant reduction of infestation occurred from Ambush and Pounce applications.

The main factors possibly determining the results of either experiment were that both orchards were initially heavily infested with NOW, and that the application was two to three weeks late. An earlier application might have significantly reduced the NOW population enough to affect infestation at harvest, and should be further explored.

Table 3 presents the mean rating of mite damage in treated and untreated trees. All trees treated with insecticide also received an application of Plictran 50W. It appears that the application did not produce any appreciable control whereas the ground application did. This may indicate that the ground application does a more thorough job of penetrating the canopy and enhancing control.

Table 2. Late Season Air Application of Permethrin for Control of NOW.

Variety	Orchard	Treatment	Lb a.i.[1] per acre	Gal H_2O per acre	Trt date	Avg. %[2] infes- tation	Harvest date
Merced	14H	Ambush	0.2	40	8/30	69 NS	10/11
		Check	--	--	--	51 NS	10/11
Merced	14G	Pounce	0.2	40	8/30	38 NS	10/11
		Check	--	--	--	46 NS	10/11
Nonpareil	14H	Ambush	0.2	40	8/30	64 NS	9/19
		Check	--	--	--	60 NS	9/19
Nonpareil	14G	Pounce	0.2	40	8/30	59 NS	9/19
		Check	--	--	--	62 NS	9/19

1/ Includes Plictran 50W, 1 lb a.i. per acre and ZNP, 2 quarts per acre.

2/ Based on 3000-nut sample per treatment.

Table 3. Effects of a Late Season Application of Permethrin and Plictran on Spider Mites.

Variety	Orchard	Treatment	Application method	Lb a.i. per acre	Gal H_2O per acre	Treatment date	Sample date	Mean[1/3/] rating
Merced	14G	Plictran 50W[4/]	Air	1.0	50	8/30	9/19	3.2
Merced	14G	Untrtd. Check	--	--	--	--	9/19	3.0
Nonpareil	14G	Plictran 50W[4/]	Air	1.0	40	8/30	9/19	3.0
Nonpareil	14G	Untrtd. Check	--	--	--	--	9/19	3.0
								[2/3/]
Merced	11A	Plictran 50W[4/]	Ground	1.0	400	8/28-8/29	9/23	1.4
Merced	11A	Untrtd. Check	--	--	--	--	9/23	2.7
Nonpareil	11A	Plictran 50W[4/]	Ground	1.0	400	8/28-8/29	9/23	1.5
Nonpareil	11A	Untrtd. Check	--	--	--	--	9/23	2.2

[1/]Based on samples of 50 trees per treatment

[2/]Based on samples of 60 trees per treatment

[3/]Rating system used: 0 = no mite damage, 1 = slight mite damage, 3 = moderate mite damage, 4 = severe mite damage.

[4/]Plictran applied in conjunction with permethrin.

Relationship Between Almond Orchard Mummy Sanitation and Navel Orangeworm Infestation

C. E. Engle and M. M. Barnes

The navel orangeworm (NOW) overwinters in mummy almonds that fail to shake free at harvest. The larvae develop through the winter at a reduced rate in this cool orchard environment. In the spring, the larvae emerge as adults from these mummies and lay eggs back on the mummy nuts which are their major food source and shelter. The resulting NOW generation develops on these same orchard mummies and emerge as adults as the current year's crop begins to hullsplit. In the past it has been shown that a "thorough" orchard mummy clean-up can reduce infestation at harvest as much as 50% without the use of pesticides. Because there is a certain amount of difficulty and expense involved in orchard sanitation, growers need quantitative information concerning average mummies per tree and its relationship to NOW infestation at harvest.

Experiments were conducted this season to arrive at a preliminary value for how clean, based on average mummies per tree, an orchard must be to reduce infestation at harvest. It is hoped that this information will allow growers either to incorporate this practice into their current NOW control program or to use as an alternative to current practices.

Eight almond orchards between the ages of 9-15 years were selected for the experiment. All orchards except three had the Mission variety as one of the pollinators; the other three had only soft-shelled pollinators.

The orchards were selected for their relative isolation from possible NOW sources such as an almond, walnut or citrus orchard. Within each orchard, a 50-acre block was selected and within this block a subplot, consisting of a 20 tree by 20 tree corner section totaling 4-5 acres, was used (Fig. 1) for the experiment. During February and March mummy nuts on every tree in each 5-acre subplot were counted and recorded (Tables 1 and 2). In the remaining 45 acres mummy nuts were also counted. However, instead of every tree, only every third tree was examined in every third row. This examination of the perimeter plot was to determine the numbers of mummies for possible NOW overwintering sites. If the numbers of mummies in the surrounding 45 acres exceeded that of the smaller 5-acre subplots, they were removed by poling. The majority of the perimeter plots received at least one pesticide application in May or June which further reduced the possibility of higher NOW populations migrating to the 5-acre plots. The subplot and perimeter plot were both examined in March and June prior to spring moth emergence and again in July at hull-split. Mummy nut drop, attributed to natural forces, i.e. wind, rain, birds, was recorded for the period March through June. In all orchards NOW larvae were sampled at the same time as the mummy counts. Larval counts were made by removing between 40-250 soft-shelled mummies and between 50-100 hardshelled mummies per orchard which were taken back to the lab and examined for NOW (Tables 1 and 2). Just prior to moth emergence in late March, all grounded nuts were mechanically flailed to eliminate any fallen nuts as a potential NOW source. There were ten oviposition traps, five in every other tree in each of two rows, at least fifty feet apart, in the center of each 5-acre plot. The traps

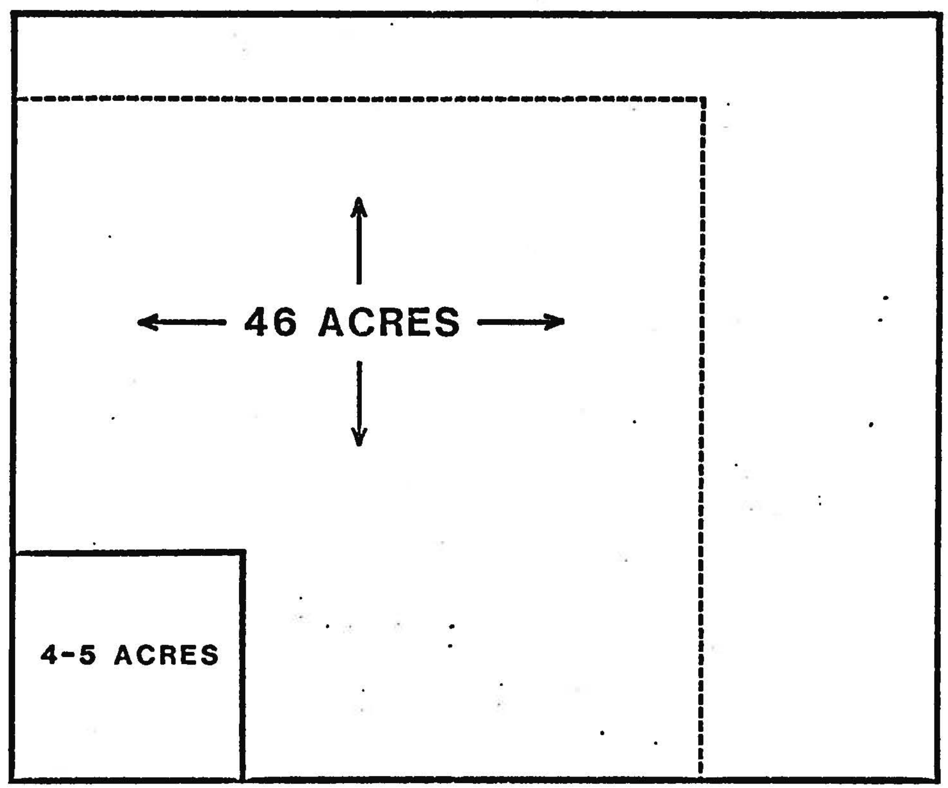

Fig. 1. Schematic representation of almond orchard with 4-5 acre subplot and 46-acre perimeter plot.

Table 1. Mean number of soft and hard shell mummy nuts per tree and mean number of larvae per mummy nut and per acre.

Feb. 8 1980

Ranch #	Mean no. soft shell mummy nuts/tree	Mean no. hard shell mummy nuts/tree	Mean no.1/ larvae/soft shell mummy nut	Mean no.2/ larvae/hard shell mummy nut	Mean no. larvae/ acre
R-94 A	2.0	214	0.09	0.00	9.8
R-94 B	2.6	N/A3/	0.20	N/A	36.4
R-94 C	10.1	75.2	0.66	0.34	686
R-88	10.5	43.9	0.56	0.24	466
R-15	14.3	57.2	1.19	0.08	1045
C-152	28.6	N/A	0.17	N/A	438
MAZY	0.919	8.4	0.24	0.04	16.8
2483	37.0	N/A	2.14	N/A	5543

1/Samples consisted of between 50 and 100 nuts per orchard. No more than 2 nuts per tree were sampled.

2/Samples of 50 nuts per orchard were taken. No more than 2 nuts per tree were sampled.

3/No hard shell pollenators in orchard.

Table 2. Mean number of soft and hard shell mummy nuts per tree and mean number of larvae per mummy nut and per acre.

Mar. 17 1980

Ranch #	Mean no. soft shell mummy nuts/tree	Mean no. hard shell mummy nuts/tree	Mean no.[1/] larvae/soft shell mummy nut	Mean no.[2/] larvae/hard shell mummy nut	Mean no. larvae/ acre
R-94 A	0.85	59.6	0.12	0.0	6.0
R-94 B	1.71	N/A[3/]	0.56	N/A	68
R-94 C	0.95	12.0	0.30	0.27	54
R-88	2.5	12.3	0.34	0.0	51
R-15	0.21	4.9	1.17	0.07	19
C-152	4.8	N/A	0.23	N/A	121
MAZY	0.48	2.1	0.56	0.0	2
2483	2.6	N/A	1.13	N/A	209

[1/]Samples consisted of between 40 and 231 mummy nuts per orchard. No more than 2 nuts per tree were sampled.

[2/]Samples consisted of between 58 and 117 mummy nuts. No more than 2 nuts per tree were sampled.

[3/]No hard shell pollenators in orchard.

were placed from chest to head height on the northeast corner of the tree canopy. All traps were replaced regularly on a 7-day schedule. The exposed traps were taken to the laboratory and examined for NOW eggs. The oviposition traps were used throughout the season, terminating at harvest (Table 3). The harvest date of a particular orchard was based on the physiological maturity of the nuts. Orchard trees were harvested when nut hullsplit averaged 95-100% at the 4-6 ft level (Table 4). At harvest, twenty trees were sampled from the center of each plot; 200 nuts were taken from each tree, totaling 4000 nuts per plot. Nuts were knocked onto tarps, bagged and taken back to the laboratory for examination. Infestation was determined by hand hulling compared to commercial hulling, which underestimates field infestation (Table 4).

Results

For all orchards the average mummy counts per tree taken in February and March were correlated with their respective larvae per acre estimates. The values $r = .81$ and $r^2 = .66$ were significant. However, when orchards with only soft-shelled mummies were eliminated from the analysis, the correlation values were $r = .97$ and an $r^2 = .94$ (Fig. 2). This high correlation between numbers of mummies and number of overwintering larvae per acre indicates that larval sampling may not be necessary. We may be able to depend solely on mummy counts to estimate NOW populations in an orchard. Tests this coming season will help verify this assumption. Three variables of navel orangeworm oviposition, determined using oviposition traps, were examined for their relationships to infestation at harvest. They were: (1) total egg counts per season, (2) peak oviposi-

Table 3. Navel orangeworm oviposition[1] taken from eight different Almond Orchards vs Percent Infested Almonds at Harvest[2]

N.O.W. OVIPOSITION 1980

ORCHARDS SAMPLED	SEASON TOTAL	PEAK EGG LAYING	SEASON AVERAGE	% INFEST. NUTS (HARVEST)
2483	7.5	1.9	0.36	5.97
MAZY	8.1	2.8	0.38	4.5
C-152	16.4	8.4	0.78	2.27
94-A	8.2	1.2	0.39	3.6
94-B	6.7	2.2	0.32	4.2
94-X	29.5	7.2	1.40	10.9
R-88	11.9	3.5	0.57	1.7
R-15	20.0	3.8	0.95	3.0

1/ Based on oviposition traps; calculated as eggs per trap per day.

2/ Harvest samples consist of 4000 nuts per orchard.

Table 4. Number of mummy nuts per tree in June and final percent infested nuts at harvest.

Jun 30 1980

Ranch #	Mean no. soft shell mummy nuts/tree	Mean no. hard shell mummy nuts/tree	Harvest Date	Percent Damaged Nuts at Harvest[1/]
R-94 A	0.3	28	8-19	3.6
R-94 B	1.2	N/A	8-19	4.2
R-94 X	20.1	N/A	8-14	10.9
R-88	0.6	5.2	8-13	1.70
R-15	0.1	0.3	8-13	3.0
C-152	0.3	0.6	8-12	2.3
MAZY	0.2	N/A	8-25	4.5
2483	1.9	N/A	8-25	6.0

[1/] Based on 20 nuts per orchard with a subsample of 200 nuts per tree, totaling 4000 nuts per orchard.

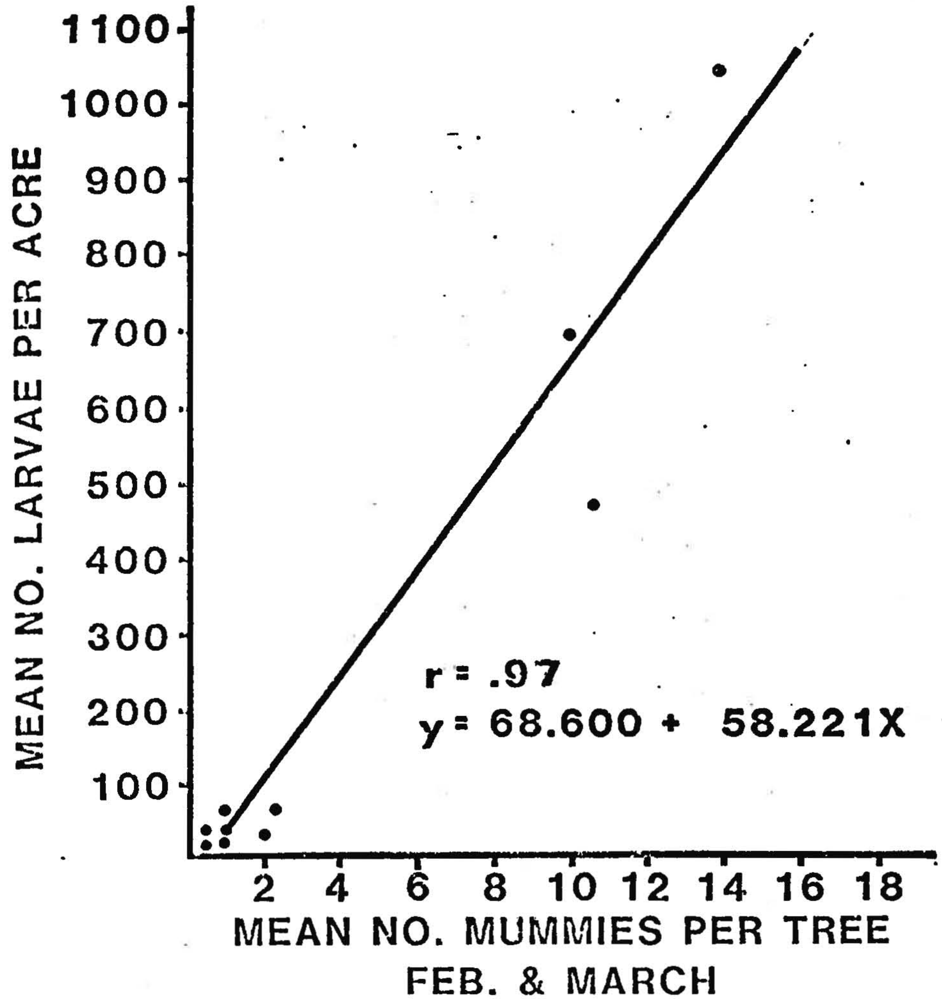

Fig. 2. Mummy nuts per tree in relation to mean number larvae per acre.

tion, and (3) average egg laying for the season (Table 3). There were no significant correlations between any of the three variables and infestation at harvest.

At harvest average infestation per orchard was correlated with average numbers of mummies per tree in June (Fig. 3). The regression equation y = 3.339+.3828X has a correlation coeffecient of r = .91. This high correlation coefficient may indicate the usefulness of mummy counts for predicting infestation at harvest. Average mummy nut drop from natural causes was examined on an individual orchard basis in March and June and ranged from 25% drop to 94% drop; the average for all orchards being 52%. This information, though variable, should be useful in the future as an aid in predicting expected nut drop.

Summary

It is an accepted fact that orchard mummy clean-up can greatly reduce NOW infestation of almonds at harvest. We attempted through these experiments to clarify the quantitative parameters of an orchard clean-up. There is strong evidence supported by our data that NOW infestation can be predicted with mummy counts. This is a great advantage over larval counts because of the relative ease in taking mummy counts as compared to laboratory examination of mummies for larvae. Mummy counts in June were a good indicator of expected infestation at harvest. These data indicate that a grower would want an average of one or less mummies per tree in June. Such low counts were easily obtained in several of the sampled orchards. The average number of mummies per tree declined 52% from March to June, possibly allowing the grower a little more flexibility in his

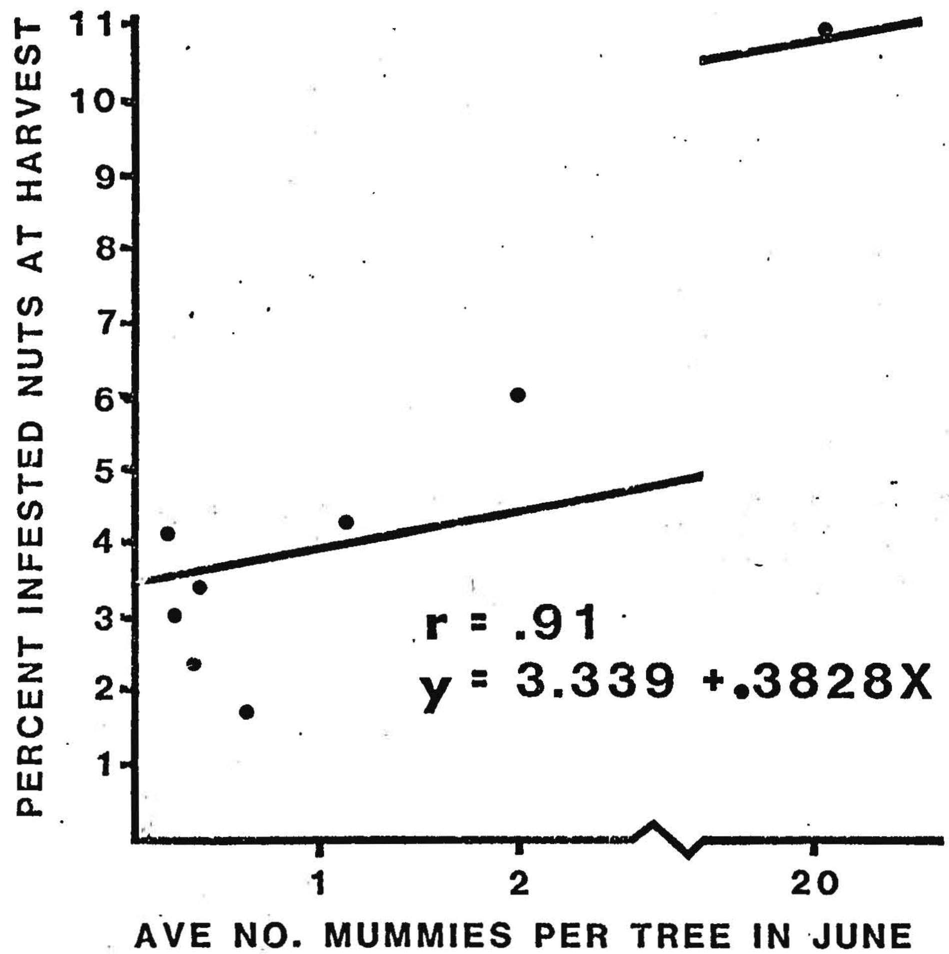

Fig. 3. Relationship between almond mummies per tree in June and percent infested nuts at harvest (each point represents 4000 nuts taken at random from one subplot).

winter clean-up, i.e., he may be able to leave two mummies per tree in mid-winter and still have the desired low numbers needed. It should also be remembered that absolutely no insecticides were used in these plots.

If currently recommended insecticides are used, a grower can generally expect 40-60% control of NOW. This control method, however, in conjunction with orchard mummy clean-up and early harvest should greatly reduce NOW damage.

Egg traps were useful only in letting us know that adult emergence was underway and either increasing or decreasing. Egg traps were, however, of no predictive value in this experiment.

To provide for management of NOW based solely on orchard sanitation and prompt harvest, the second vital requirement, the following tentative standards, based on one year's experience, are suggested:

A. Use orchards that are at least 0.5 miles from external source of infestation, i.e., almonds, walnut, citrus.

B. Clean orchard in winter to an average of one mummy per tree.

C. Blow mummies off burms and flail prior to March 15.

D. Harvest promptly at 95-100% hullsplit measured below six feet. If all requirements cannot be met, your NOW control program should be supplemented by the use of insecticides.

Navel Orangeworm Oviposition: Rate and Quantity at Various Constant Temperatures

C. E. Engle and M. M. Barnes

Experiments were conducted to establish several parameters of navel orangeworm (NOW) oviposition. Total number of eggs and rate of egg production per day were examined at various constant temperature regimes. A temperature threshold for oviposition was also investigated.

Method

Laboratory-reared pupae were sexed and placed in separate, screened emergence cages. The pupae were placed in an 80°F constant temperature room with a 14:10 photoperiod. Freshly emerged moths were collected and placed in 15X20 cm glass battery jars. The jars were lined top and bottom with paper toweling and a 6X18 cm strip of toweling was placed the length of one side of the jar. The lining and strip of toweling allowed the moths resting and oviposition sites. Ten males and ten females were placed in each jar and put in constant temperature cabinets with 14:10 photoperiod. Oviposition was recorded daily until all females were dead or egg laying had ceased for three consecutive days. Moth mortality was tabulated daily.

Summary

Oviposition is strongly affected by temperatures. Tables 1 and 2 list the total egg production, percent eggs laid per day and the total number of eggs laid per 10 females at a given constant temp. The data indicate that temperature can strongly affect the total number of eggs

Table 1. Navel orangeworm oviposition, replicate[1/] totals and treatment totals, at various constant temperatures.

TEMP. °F	REPLICATE I	REPLICATE II	REPLICATE III	TOTALS
55	257	259	282	798
60	923	1254	1259	3436
65	1463	2102	2315	5880
70	503	1971	2333	4807
80	463	2037	1839	4339

1/ Replicates based on 10 females each.

laid. Under the existing conditions optimum temperature for maximum egg production is 65°F; moths at this temperature laid more than seven times the total amount of eggs laid at 55°F.

Table 2 lists the days required at a given temperature for NOW to oviposit 25, 50, 75, and 95 percent of the total eggs laid. The rapidity with which eggs are laid after mating does not suggest an optimum oviposition temperature but merely the moths increased rate of response to temperature. At 80°F, 95% of all eggs were laid in six days but at 55° it required almost three times as long to lay the same percentage eggs. Figure 1 depicts the rate of NOW oviposition at various constant temper-a tures. There is a strong linear relationship between temperature and rate of egg laying with the regression equation Y = 30.737+.5762X having a correlation coefficient of r = .98. This linear relationship between temperature and rate of egg laying can be extrapolated to the intercept of the X axis giving an oviposition temperature threshold of 53.3°F. This oviposition threshold for egg laying may provide a temperature indicator in the spring for beginning moth oviposition.

Table 2. Number of days required by navel orangeworm[1/] at various constant temperatures to oviposit 25% through 95% of their eggs.

TEMP. °F	NAVEL ORANGEWORM DAYS FOR OVIPOSITION OF: 25%	50%	75%	95%
55	4	6	11	17
60	3	6	10	16
65	2	4	6	10
70	2	4	5	10
80	2	3	4	6

[1/] Based on 3 replicates of 10 females NOW each.

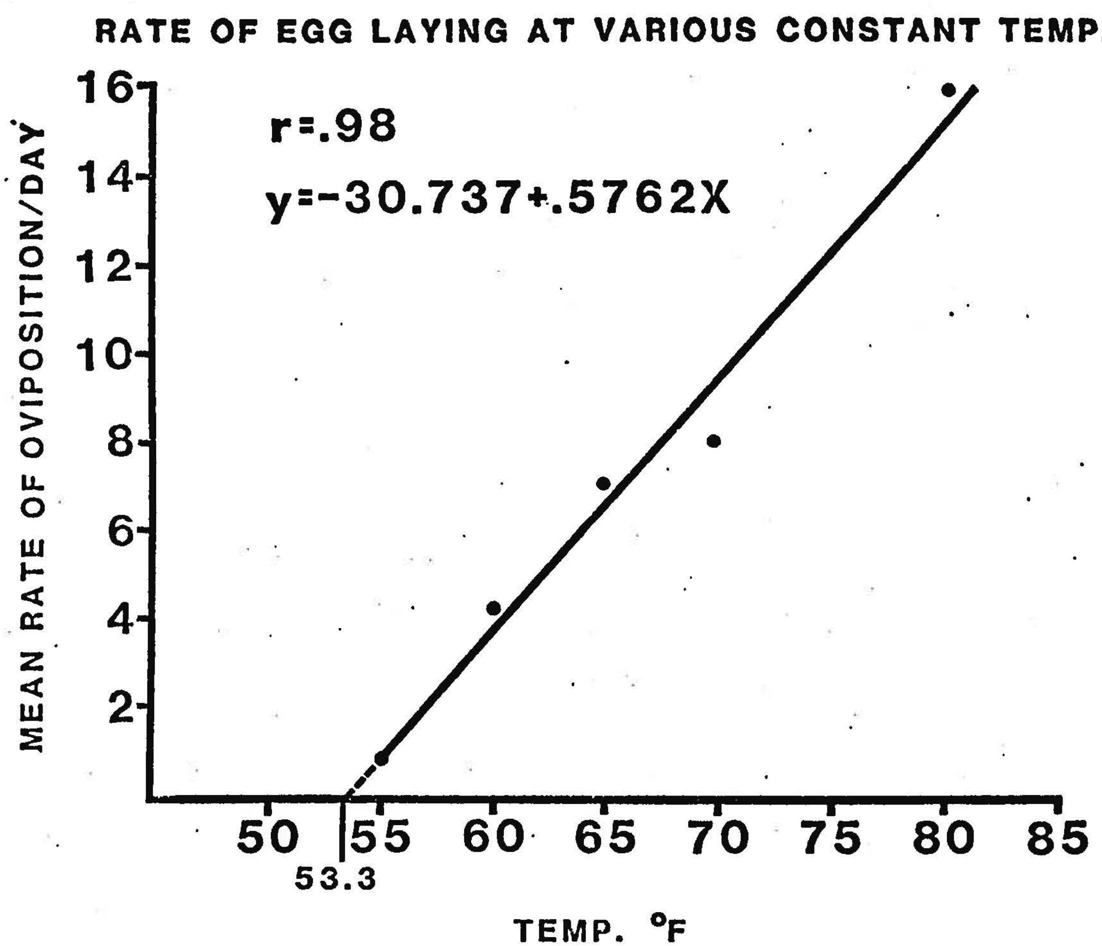

Fig. 1. Average rate of oviposition at five constant temperature regimes.

Day-Degree Summation for Navel Orangeworm Pupae Development

C. E. Engle and M. M. Barnes

An experiment was conducted to determine the theoretical developmental threshold and number of degree-hours required by navel orangeworm (NOW) pupae to emerge as adults.

Materials and Methods

NOW larvae were reared at a constant 80°F on a diet of red wheat bran, glycerin and honey. These larvae, upon reaching the late 6th instar, were checked every 2 hours for pupation (indicated by the loss of the head capsule). Once pupation began, 5-15 pupae were placed in 7 cm X 7 cm sealed plastic cups. The plastic cup was filled 1/4 full with potassium hydroxide to maintain relative humidity at 90%. The containers were placed in constant temperature cabinets ranging in temperature from 65-90°F with 14:10 photoperiod. Temperature and adult emergence were recorded 3-4 times daily. The procedure described by Arnold (1959) was utilized to determine the threshold temperature for pupal development.

Results:

The relationship of development per hour to temperature is shown in Fig. 1. The regression equation $y = 1.183+.0212X$ has a correlation co-efficient of 0.97. The intercept of 55.6 degrees fahrenheit of the extrapolated regression line is the temperature threshold for pupal development. The reciprocal of the regression slope value gives an average heat unit accumulation of 4702 degree-hours. Fig. 1 presents the

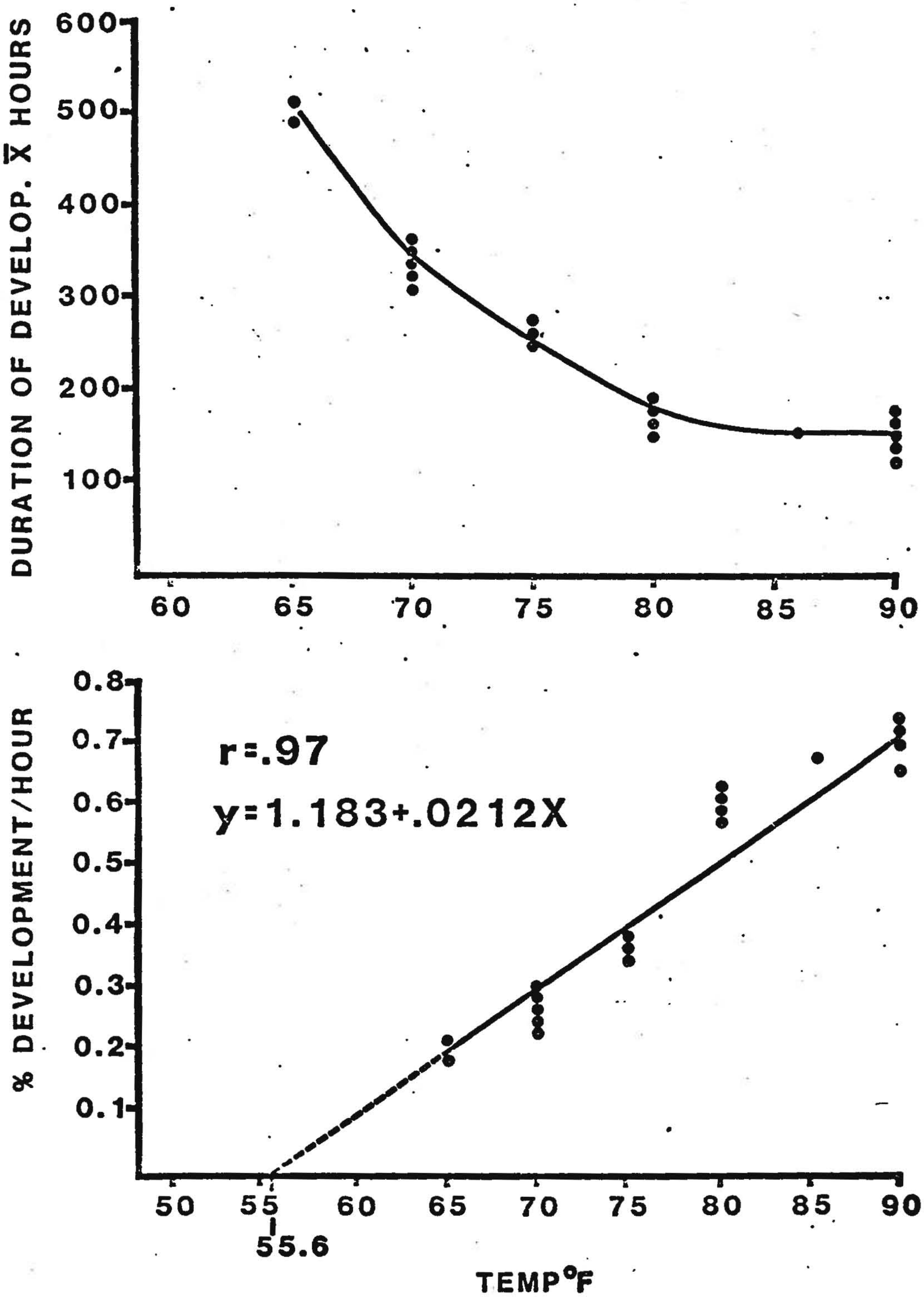

Fig. 1. Duration of Development vs. Percent of Development per hour for NOW pupae at constant temperature.

duration of development in hours at various constant temperatures, from which our rate of development was tabulated. At present we are in the process of field validating the developmental threshold and degree-hours required for pupal emergence. This field data will be contrasted to our laboratory data.

Field Acaricide Trials

S. C. Welter and M. M. Barnes

The efficacy of 11 treatments was evaluated during July and August of 1980 in the southern San Joaquin Valley. The compounds UC55248, L-676863, Mitac, SLJ0312, Ambush, and DPX 3792 were compared to two currently registered acaricides, Omite and Plictran, as well as to an unsprayed check. The effects on both the phytophagous and predatory mites or insects were determined for each treatment. The applications were made on July 28, 1980 within a 5-year-old drip irrigated orchard located approximately 15 mi northeast of Wasco, Kern Co.

Materials and Methods

Applications were made with a high pressure handgun which delivers a fine spray at 400-450 psi. The trees were sprayed with an average of 10 gal of dilute spray per tree, resulting in an application rate of approximately 700 gal/acre.

Leaves were picked from all four sides of the tree between the heights of 1.5-2.0 m. Six leaves were taken from each of the four quadrats for a total sample of 24 leaves per tree. The leaves were kept refrigerated until counts were made under a stereoscope.

A randomized block design composed of 5 blocks was established within the orchard. Four blocks consisted of the Nonpareil variety and one block consisted of the Texas Mission variety.

Thirty male spider mites were mounted for species identification. The population consisted entirely of *Tetranychus pacificus*, pacific mite.

Results

As shown in Table 1, all treatments performed equally well after 24 hrs with the check treatment population continuing to increase. After 72 hrs, the Ambush treated trees were no longer statistically different from the check treatment. All other treatments were not statistically different from each other except L-676863 at an application rate of 4 ppm which proved significantly higher statistically than the Plictran application.

Except for the check and Ambush treatments, no statistical difference was discernible after 1 week. Both the check and Ambush treatment populations continued to increase in numbers.

By the second week, the check treatment started to decline while the Ambush treated mite populations continued to rise. The compounds Omite, Plictran, SLJ0312 and Mitac at 8 oz ai/100 gal could be discerned as being statistically lower than the check. Yet, none of the various acaricide treatments except Ambush could be separated from each other in regard to efficacy.

By the 3rd week after application, all treatments except the Ambush treated trees lacked any significant levels of mites. Samples taken 4 and 6 weeks after application failed to show any difference between any treatments because of the rapid decline of mites in the Ambush treated trees.

The rapid decline of both the Ambush and check treatments may possibly be explained through examination of the levels of predators found within each treatment.

Within the check trees the numbers of sixspotted thrips, Scolothrips sexmaculatus, demonstrated a 23.5-fold increase within an 18-day period as shown in Table 2 and Figure 1. The rise in numbers of sixspotted thrips per leaf appears to be responsible for the observed decline of spider mites within the check trees.

A similar trend was observable within the Ambush treated trees. The initial application of Ambush appears to have provided some degree of mortality due either to the inherent toxic nature of the compounds or a simple washing off of a portion of the population with the high pressure application.

The mite population within the Ambush treated trees increased more slowly than the check trees. In addition, a similar increase in sixspotted thrips was observed to parallel the mite population growth. The mite population growth appears to have been checked by the increase in the sixspotted thrips population.

While the thrips population did appear to provide control, the mite feeding had already resulted in significant scarring of the leaf as well as some defoliation of the trees.

As shown in Table 3, the native phytoseiid predatory mite population did show an increase after one week within the check, but was at extremely low numbers after two weeks. An increase in predatory mites was not evident within the Ambush treated trees.

Based upon a visual examination on 8/25/80, no phytotoxic response was observed within any of the acaricide treatments.

Table 1.--Mean number of mobile stages of Pacific mite per leaf[a/], Kern Co., CA. July 1980[b/].

	Compound	Rate[c/] a.i.	Sample							
			Pretreat 7/24	1 day 7/29	3 day 7/31	1 week 8/4	2 week 8/11	3 week 8/18	4 week 8/25	6 week 9/8
1.	UC55248 4.0 EC	8 oz/100 gal	2.6 a	0.4 b	0.3 cd	0.4 b	0.3 bc	0.0 b	0.0 a	0.0 a
2.	L-676863 .04 EC	4 ppm	6.4 a	0.3 b	1.6 bc	1.4 b	0.7 bc	0.1 b	0.0 a	0.0 a
3.	L-676863 .04 EC	8 ppm	3.3 a	0.1 b	0.5 cd	0.8 b	1.4 bc	0.1 b	0.0 a	0.0 a
4.	L-676863 .04 EC	16 ppm	2.0 a	0.2 b	1.3 cd	1.0 b	0.6 bc	0.0 b	0.0 a	0.0 a
5.	Mitac 1.5 EC	4 oz/100 gal	2.3 a	0.0 b	0.3 cd	0.2 b	0.1 bc	0.0 b	0.0 a	0.0 a
6.	Mitac 1.5 EC	8 oz/100 gal	4.5 a	0.0 b	0.1 cd	0.0 b	0.0 c	0.0 b	0.0 a	0.0 a
7.	SLJ0312 50 WP	8 oz/100 gal	1.9 a	0.1 b	0.1 cd	0.2 b	0.0 c	0.0 b	0.0 a	0.0 a
8.	Ambush 2.0 EC	.9 oz/100 gal	2.5 a	1.4 b	2.9 ab	3.3 b	5.4 a	3.6 a	0.1 a	0.0 a
9.	Plictran 50 WP	3 oz/100 gal	2.5 a	0.0 b	0.0 d	0.1 b	0.0 c	0.1 b	0.0 a	0.0 a
10.	Omite 30 WP	7.2 oz/100 gal	3.8 a	0.2 b	0.6 cd	0.0 b	0.0 c	0.0 b	0.0 a	0.0 a
11.	DPX3792 2.0 EC	2.3 oz/100 gal	4.1 a	0.2 b	0.4 cd	0.9 b	0.9 bc	0.0 b	0.0 a	0.0 a
12.	Check	—	1.9 a	9.2 a	3.8 a	11.0 a	2.6 b	0.1 b	0.0 a	0.0 a

[a/] Based on 5 replicates of 24 leaves/tree.

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

[c/] Applied with high pressure handgun at 700 gal/acre.

Table 2.--Mean number[a] of sixspotted thrips[b] per leaf, Kern Co., CA. July 1980[c].

	Compound	Rate[d] a.i.	Sample: Pretreat 7/24	1 day 7/29	3 day 7/31	1 week 8/4	2 week 8/11	3 week 8/18	4 week 8/25	6 week 9/8
1.	UC 55248 4.0 EC	8 oz/100 gal	0.05 a	0.0 a	0.0 c	0.05	0.13 b	0.09 bcd	0.02 b	0.0 a
2.	L-676863 .04 EC	4 ppm	0.06 a	0.0 a	0.0 c	0.19 b	0.16 b	0.18 bc	0.0 b	0.0 a
3.	L-676863 .04 EC	8 ppm	0.04 a	0.0 a	0.0 c	0.14 bc	0.13 b	0.12 bcd	0.01 b	0.0 a
4.	L-676863 .04 EC	16 ppm	0.02 a	0.0 a	0.0 c	0.07 bc	0.11 b	0.04 c	0.0 b	0.0 a
5.	Mitac 1.5 EC	4 oz/100 gal	0.02 a	0.0 a	0.0 c	0.04 b	0.04 b	0.02 c	0.0 b	0.0 a
6.	Mitac 1.5 EC	8 oz/100 gal	0.02 a	0.0 a	0.0 c	0.0 c	0.0 b	0.0 d	0.0 b	0.0 a
7.	SLJ 0312 50 WP	8 oz/100 gal	0.0 a	0.0 a	0.0 c	0.0 c	0.0 b	0.01 d	0.0 b	0.0 a
8.	Ambush 2.0 EC	.9 oz/100 gal	0.01 a	0.0 a	0.06 ab	0.09 bc	0.11 b	0.42 a	0.09 a	0.0 a
9.	Plictran 50 WP	3 oz/100 gal	0.02 a	0.0 a	0.0 c	0.0 c	0.06 b	0.02 c	0.0 b	0.0 a
10.	Omite 30 WP	7.2 oz/100 gal	0.0 a	0.0 a	0.01 bc	0.04 bc	0.02 b	0.02 c	0.0 b	0.0 a
11.	DPX 3792 2.0 EC	2.3 oz/100 gal	0.07 a	0.0 a	0.02 abc	0.12 bc	0.21 b	0.13 bcd	0.0 b	0.01 a
12.	Check	-	0.03 a	0.04 a	0.07 a	0.5 a	0.94 a	0.2 b	0.02 b	0.0 a

a/ Based on 5 replicates of 24 leaves per tree.

b/ Family - Thripidae: Scolothrips sexmaculatus.

c/ Means in the same column followed by the same letter are not significantly different at the P = .05 level using Duncan's new multiple range test.

d/ Applied with high pressure handgun at 700 gal/acre.

Table 3.--Mean number[a] of predatory mites[b] per leaf, Kern Co., CA. July 1980[c].

		Sample							
Compound	Rate[d] a.i.	Pretreat 7/24	1 day 7/29	3 day 7/31	1 week 8/4	2 week 8/11	3 week 8/18	4 week 8/25	6 week 9/8
1. UC55248 4.0 EC	8 oz/100 gal	0.16 a	0.2 a	0.06 b	0.02 a	0.0 a	0.0 a	0.0 a	0.0 a
2. L-676863 0.04 EC	4 ppm	0.15 a	0.2 a	0.12 ab	0.02 a	0.0 a	0.0 a	0.0 a	0.0 a
3. L-676863 0.04 EC	8 ppm	0.19 a	0.01 a	0.0 b	0.04 a	0.0 a	0.0 a	0.0 a	0.0 a
4. L-676863 0.04 EC	16 ppm	0.03 a	0.0 a	0.08 b	0.01 a	0.0 a	0.0 a	0.0 a	0.0 a
5. Mitac 1.5 EC	4 oz/100 gal	0.04 a	0.0 a	0.0 b	0.01 a	0.0 a	0.0 a	0.0 a	0.0 a
6. Mitac 1.5 EC	8 oz/100 gal	0.19 a	0.0 a	0.0 b	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
7. SLJ0312 50 WP	8 oz/100 gal	0.14 a	0.0 a	0.0 b	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
8. Ambush 2.0 EC	.9 oz/100 gal	0.0 a	0.0 a	0.13 ab	0.02 a	0.0 a	0.0 a	0.01 a	0.0 a
9. Plictran 50 WP	3 oz/100 gal	0.12 a	0.0 a	0.0 b	0.0 a	0.0 a	0.0 a	0.01 a	0.0 a
10. Omite 30 WP	7.2 oz/100 gal	0.0 a	0.01 a	0.06 b	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
11. DPX3792 2.0 EC	2.3 oz/100 gal	0.10 a	0.0 a	0.0 b	0.0 a	0.0 a	0.0 a	0.01 a	0.0 a
12. Check	—	.06 a	0.06 a	0.3 a	0.20 a	0.0 a	0.0 a	0.02 a	0.0 a

[a] Based on 5 replicates of 24 leaves/tree.

[b] Family: Phytoseiidae.

[c] Means in the same column followed by the same letter are not significantly different at the P=0.05 level using Duncan's new multiple range test.

[d] Applied with high pressure handgun at 700 gal/acre.

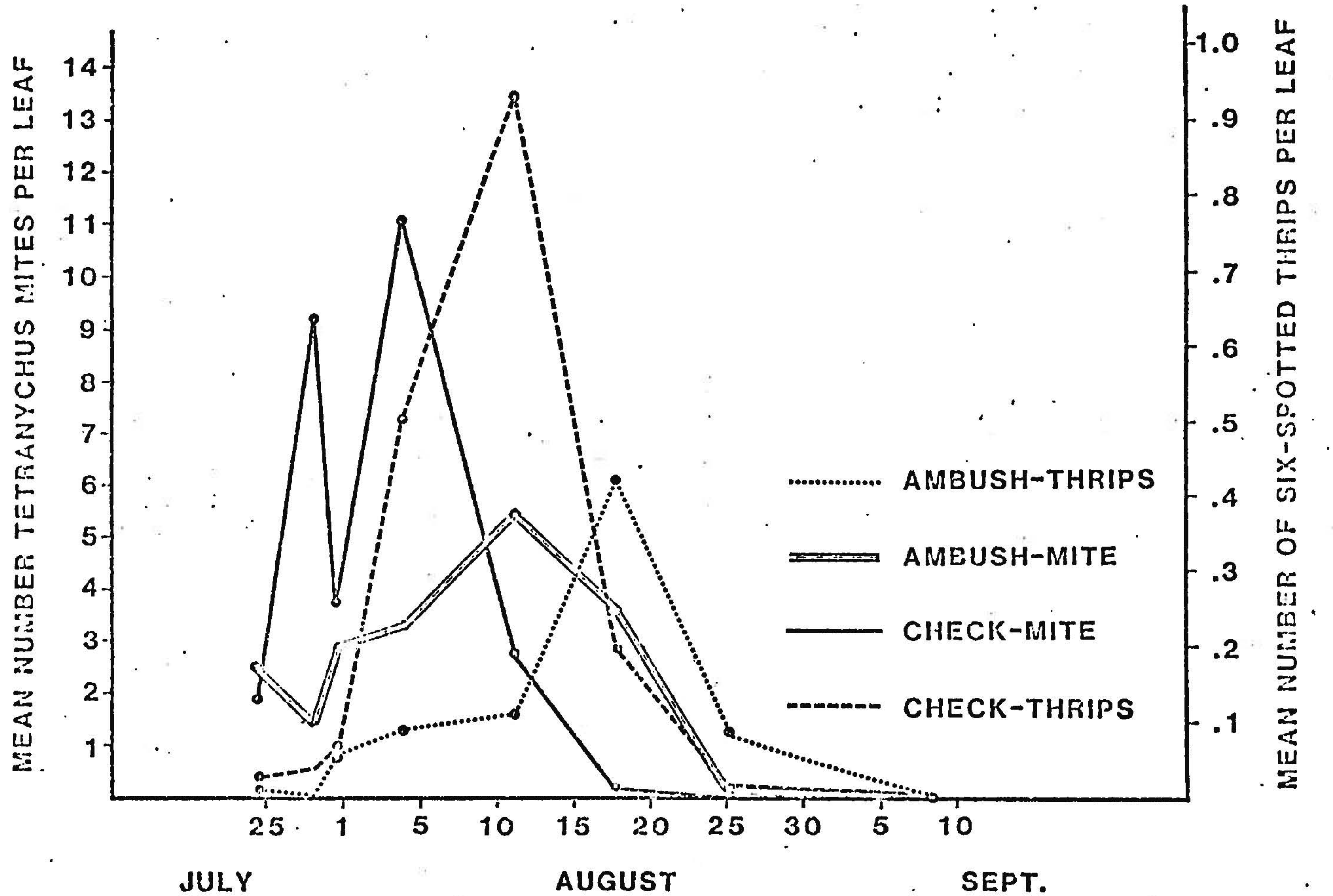

Fig. 1. Relationship between Tetranychus mite populations and sixspotted thrips populations.

Spider Mite-Almond Tree Interactions

S. C. Welter and M. M. Barnes

Between 1978 and 1980 the effects of spider mite feeding were evaluated as a stress factor upon almond tree physiological processes and productivity.

The research effort was conducted in terms of two major thrusts. The first being the effects of spider mite feeding upon the tree's growth patterns or morphology, as well as its productivity. The second thrust dealt with the effects of spider mite feeding upon an almond tree's photosynthetic and transpiration rates. Ultimately, the goal was to be able to integrate the two facets together and demonstrate a relationship between changes in the physiological processes of the almond tree due to spider mite feeding and changes in the almond tree's growth or productivity.

Relationship between Spider Mite Feeding and Almond Tree Growth and Productivity, 1978 - 1980

One aspect of our project deals with the quantification of mite damage in respect to an almond tree's growth and productivity. Previous research efforts have met with difficulties when attempting to account for the variability in normal tree growth or yield or when attempting to establish different levels of mite damage within an orchard.

The research program involved utilizing the concept of "mite-days" as means of estimating mite damage, one mite-day being defined as one mite feeding for one day. Previous research has relied primarily upon the use of mean number of spider mites per leaf as a correlate of mite damage. The use of mean number of mites per leaf as a damage estimate is dependent upon the often invalid assumption of a common mite population growth rate for different trees or orchards. As shown in Fig. 1, the use of mean number of mites per leaf fails to take into account the duration of the mite infestation. On both June 15 and August 15, the mean number of mites per leaf was 50, which would imply equal levels of mite damage based on the assumption that mean number of mites per leaf correlates with mite damage. However, if mean number of mite-days is used, then both the numbers of mites and the duration of infestation are considered. As shown in Fig. 1, the orchard had accumulated 500 mite-days per leaf by June 15, while by August 15 the orchard had accumulated 2500 mite-days per leaf. The relationship between mite-days per leaf and an almond tree's growth and productivity should be considered when an economic injury level is established for spider mites.

Materials and Methods

1978-1979 Field Trial

The large degree of variability exhibited by the tree's normal growth and yield as well as the variability in response to spider mite feeding required extensively replicated treatments. The experiment was initiated in 1978 within a four-year-old orchard located 0.5 miles south of Shafter, CA. The trees were on a 24X24 ft planting scheme within the flood-irrigated orchard. The orchard was subjected to unusual water stress throughout the season, including the withdrawal of any irrigation for a nine-week period.

Sixteen blocks of four trees each were established within two rows of the Nonpareil variety. Three different levels of mite-days were established on separate trees within each block, while the fourth tree

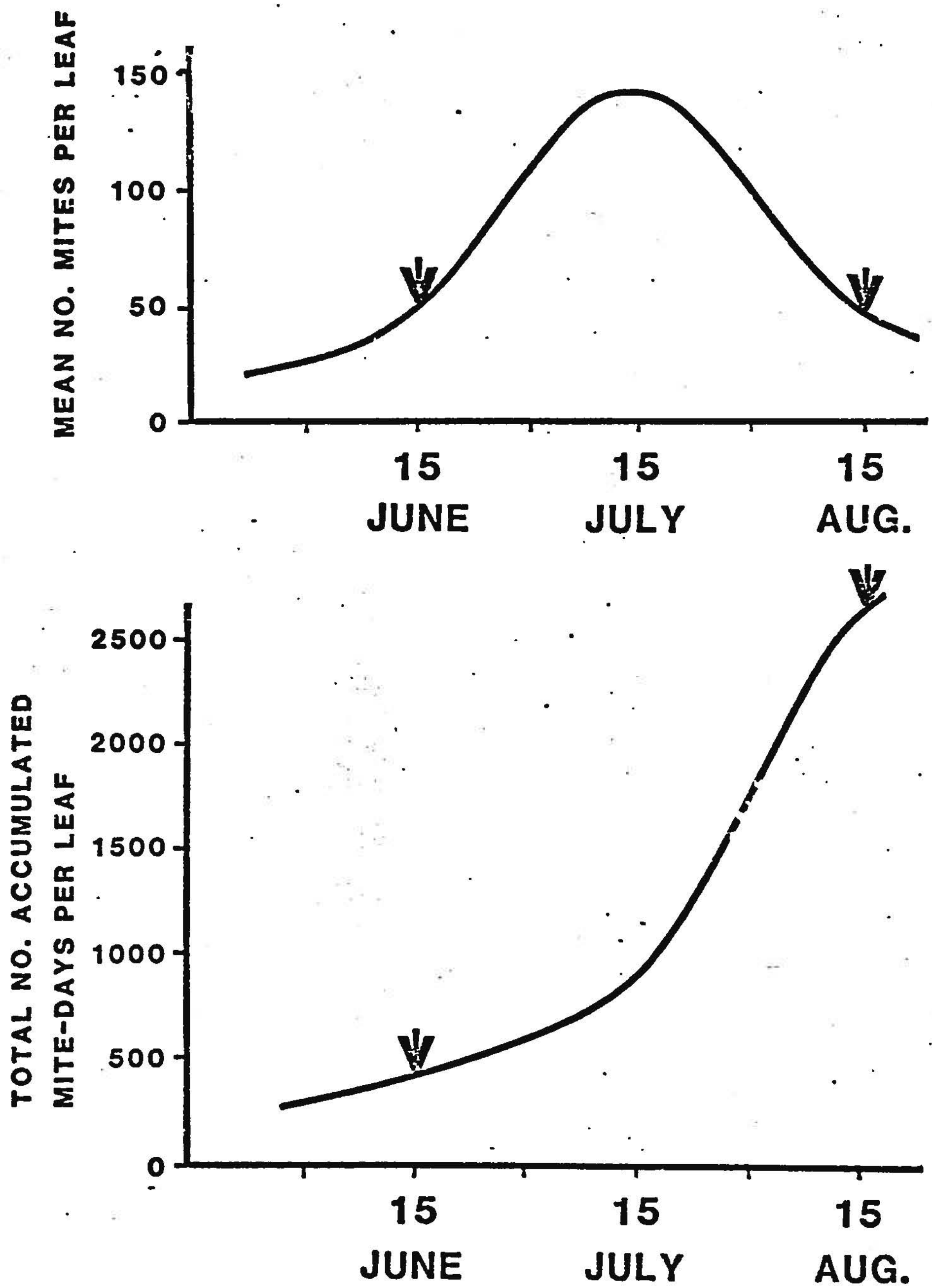

Fig. 1. Relationship of mean no. mites per leaf to total no. accumulated mite-days per leaf.

was kept mite-free with an acaricide application of Plictran 50WP. The mite populations were allowed to develop unhampered until the desired number of mite-days per leaf had accumulated. Once a tree had reached the desired number of mite-days per leaf, then Plictran 50WP was applied to keep the tree mite-free for the duration of the season.

Each tree was monitored on a weekly basis for mites from late June to September. The sampling scheme was based upon the tree being partitioned into eight sectors. The tree canopy was divided along the four points of the compass as well as into upper and lower halves. Thirty-two leaves, four from each sector, were collected from each tree and subsequently examined under a dissecting microscope. The mite species found consisted of 60% Pacific spider mite and 40% twospotted mite.

The extent of terminal shoot growth was determined by measuring nine terminal shoots per tree. The current year's growth was differentiated from previous year's growth by both the shift in color from green to brown as well as by distinct scar tissue formation.

Girth measurements were taken with a cloth tape at a height of 15 cm above the soil surface.

The mean leaf size was determined for each tree in 1979 through the use of Lamda Licor's portable area meter. Thirty-two leaves were collected at the end of the season in the same manner as leaves selected for mite population estimates.

Yield data was obtained in 1978 for each tree based upon the formula:

$$\text{lbs nutmeats/tree} = \frac{\text{total lbs whole nuts}}{\text{tree}} \times \frac{\text{Dried subsample weight}}{\text{wet subsample weight}} \times \frac{\text{lbs nutmeats for 200 nuts}}{\text{lbs nutmeats \& plant residue for 200 nuts}}$$

Results

The effects of the four treatment levels are reported in Table 1. The levels of mite-days accumulated by the four treatments ranged from treatment 1 with low levels of damage at 84 mite-days per leaf to treatment 4 with 678 mite-days per leaf. Trees within treatment 4 experienced up to 70% defoliation by early September. Treatments 2 and 3 had 311 and 517 mite-days, respectively.

A one year delay between spider mite feeding and any reduction in almond tree growth or yield was reported by Barnes and Andrews in 1978. The tree's current growth or yield was not affected by mite feeding within the same season. The lack of any significant reduction in growth or yield within the same year as mite feeding is not unexpected upon examination of the tree's growth pattern. The mite infestations did not reach high levels until late in July, while the main extension of shoots and growth of buds had already taken place by early July.

(a) Terminal growth

Terminal shoot extension was not measured in 1978 because of a severe outbreak of peach twig borer, a moth whose larva burrows down the shaft of developing shoots.

Terminal growth in 1979 exhibited significant differences between treatments. Terminal growth was significantly reduced by 23.8% in treatment 3 which had 311 mite-days per leaf. Treatment 4 also showed a significant reduction of 24.3% when compared to treatment 1. While treatment 2 did not have a statistically significant reduction, the trend towards reduced growth was evident with a 9% reduction in terminal growth. The relationship between mite-days per leaf and percent terminal growth is expressed

Table 1. Effects of Varying Levels of Mites on Almond Tree Growth and Productivity in Field Trial, 1978-1979.

Kroeker - 1978

Treatment No.	Mite-days/leaf[1/]	Terminal growth (cm)	Girth (cm)	Mean leaf size (cm^2)
1	84	NA[2/]	33.4 A	NA
2	311	NA	33.2 A	NA
3	517	NA	33.0 A	NA
4	678	NA	31.9 A	NA

Kroeker - 1979

Treatment No.	Mite-days/leaf[1/] 1979	Mite-days/leaf[1/] 1980	Terminal growth (cm)[3/]	1978-1979 change in girth	Mean leaf size (cm^2)[4/]
1	84	0	67.6 A	9.35 A	17.47 A
2	311	0	61.5 A	8.89 A	16.77 AB
3	517	0	51.5 B	8.89 A	16.34 B
4	678	0	51.2 B	8.75 A	16.18 B

[1/] Mean based on 14 replicates

[2/] NA represents "not applicable"

[3/] Mean based on 9 terminals per tree

[4/] Mean based on 32 leaves per tree

in Fig. 2. The mite-infested trees were expressed as a percentage of the check tree within the same block. The trees were placed into categories based on 50 mite-day increments and regressed against the mean percent terminal growth for each category. The relationship described by the function $y = 96.01 - 0.02X$ proved significant at the 0.01 level confidence level with a correlation coefficient of $r = -0.80$.

(b) Girth

No significant differences were observed between the treatments in 1978. Girth was evaluated in 1979 by examining the change in girth from 1978 to 1979. Again, no statistical differences were observed between the treatments, despite the trend towards reduced girth increase with increasing mite-damage. The change in girth for one year was apparently not as sensitive to mite feeding as either terminal growth or yield.

(c) Mean leaf size

Mean leaf size was not measured in 1978. In 1979 significant differences were observed between treatment 1 and treatments 3 and 4. Treatment 3 showed a 6.5% reduction in mean leaf size, while treatment 4 showed a 7.4% reduction. Treatment 2 also showed a 4% reduction in leaf size, but this difference was not statistically significant. This reduction in average leaf size may be important in terms of loss of photosynthetic area.

(d) Yield

The four treatments did not show any statistical differences in 1978 with the following respective yields: .49, .58, .61, and .53 lbs nutmeat per tree.

Yield estimates were not made in 1979.

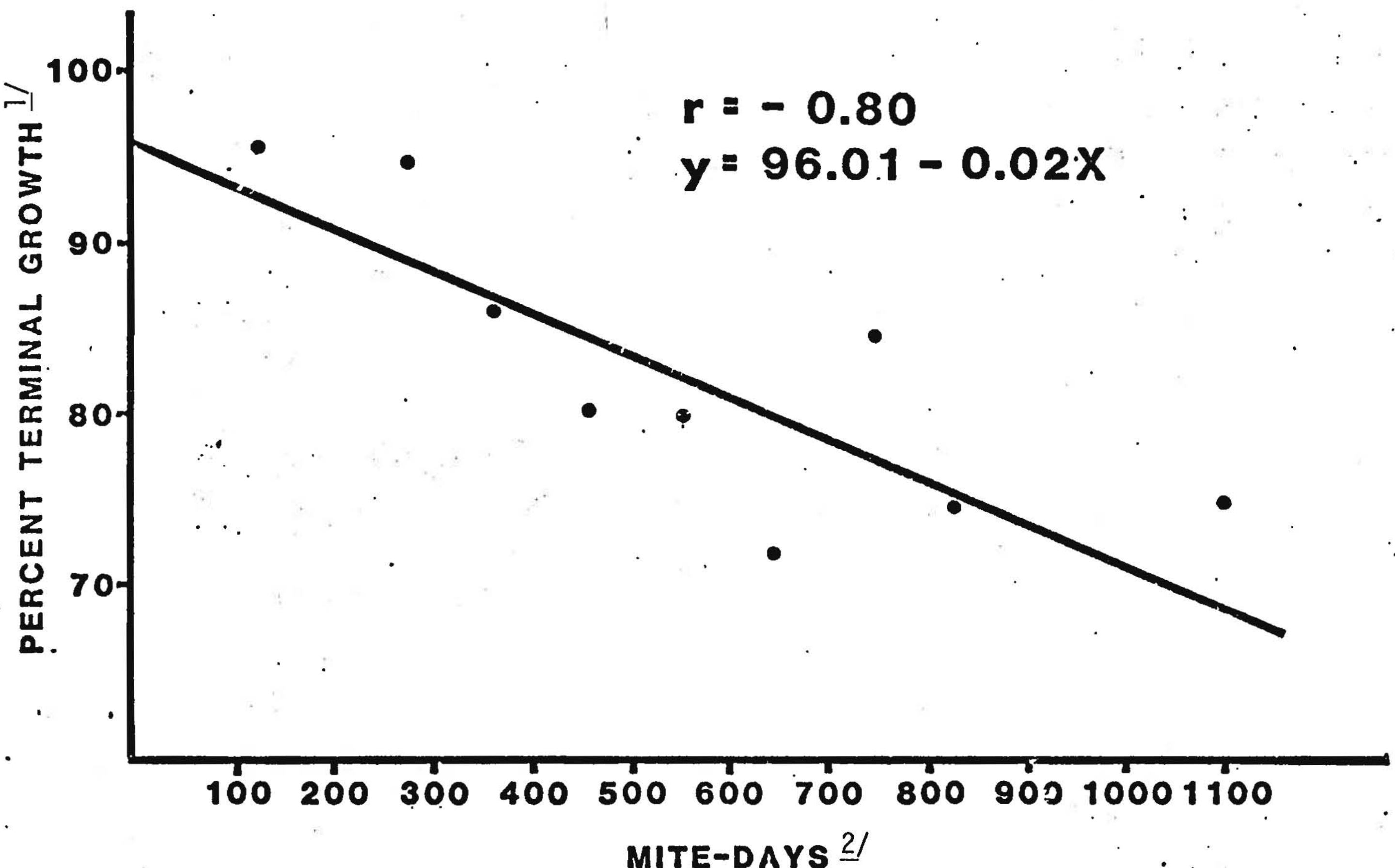

Fig. 2. Relationship of mite-days to percent terminal growth (Kroeker, 1979).

1/ Mite infested trees are expressed as a percentage of the check tree within the same block.

2/ Mite-days per leaf based on categories of 50 mite-day increments.

1979-1980 Field Trial

The effects of spider mites upon almond tree growth and yield were investigated within a well-irrigated orchard located approximately 1.5 mi north of Shafter, CA. The orchard was irrigated on a weekly basis until approximately 2.5 weeks prior to harvest.

Four treatments of varying mite-days were established within the five-year-old flood irrigated orchard. Fourteen blocks, each consisting of four trees, were established within two adjacent rows of the Nonpareil variety. Treatments 2, 3, and 4 were allowed to develop mite infestations until the desired number of mite-days per leaf had accumulated. Treatment 1 was kept mite-free throughout the season with Omite 30 WP. After each tree had accumulated the appropriate number of mite-days per leaf, an application of Omite 30WP was used to keep the tree mite-free for the duration of the season.

Mite population estimates were made in the same manner described for the 1978-1979 field trial. Mite species identification showed the mite population to be 100% Pacific spider mite. Mean leaf size, girth, and yield were also measured in the same fashion as in the 1978-1979 field trial.

In 1979, the mean terminal growth rate was based upon the measurement of the growth of nine terminals per tree. In 1980, eighteen terminals were measured to determine the mean growth rate for each tree. Only the first year's growth was included in each year's mean terminal growth.

Results

In 1979 significantly lower levels of mite-days per leaf were allowed to develop in order to define more critically a threshold level for spider mite feeding in terms of reduced growth or productivity. For the four treatments the mean number of accumulated mite-days per leaf are as follows, respectively: 116, 178, 300, and 424 mite-days per leaf.

(a) Terminal growth

In 1979, no statistical differences were detected between the four treatment levels. In 1980, treatments 3 and 4 are statistically different from treatments 1 and 2. Treatment 3 showed a 23% reduction compared to the virtually mite-free treatment 1. Treatment 4 also was reduced by 23% when compared to treatment 1. The relationship between mite-days and percent terminal growth is shown in Fig. 3. The trees were placed into categories based on 50 mite-day increments and regressed against mean percent terminal growth. The mite-infested trees are expressed as a percentage of the trees in treatment 1 within the same block. The relationship correlation coefficient of r = -0.88 indicates a strong correlation between increasing mite-days and increasing reductions in terminal shoot elongation.

(b) Girth

No statistical difference was detectable between the four treatments in either 1979 or 1980 (Table 2).

(c) Mean leaf size

In 1979 no statistical differences existed between the treatments. In 1980, no statistical differences were obtained, but a trend towards reduced leaf size was indicated. A 4% reduction in leaf size was observed within treatment 4.

(d) Yield

Yield estimates indicate no significant reductions in yield between the four treatments in 1979. In 1980 the results are expressed as a

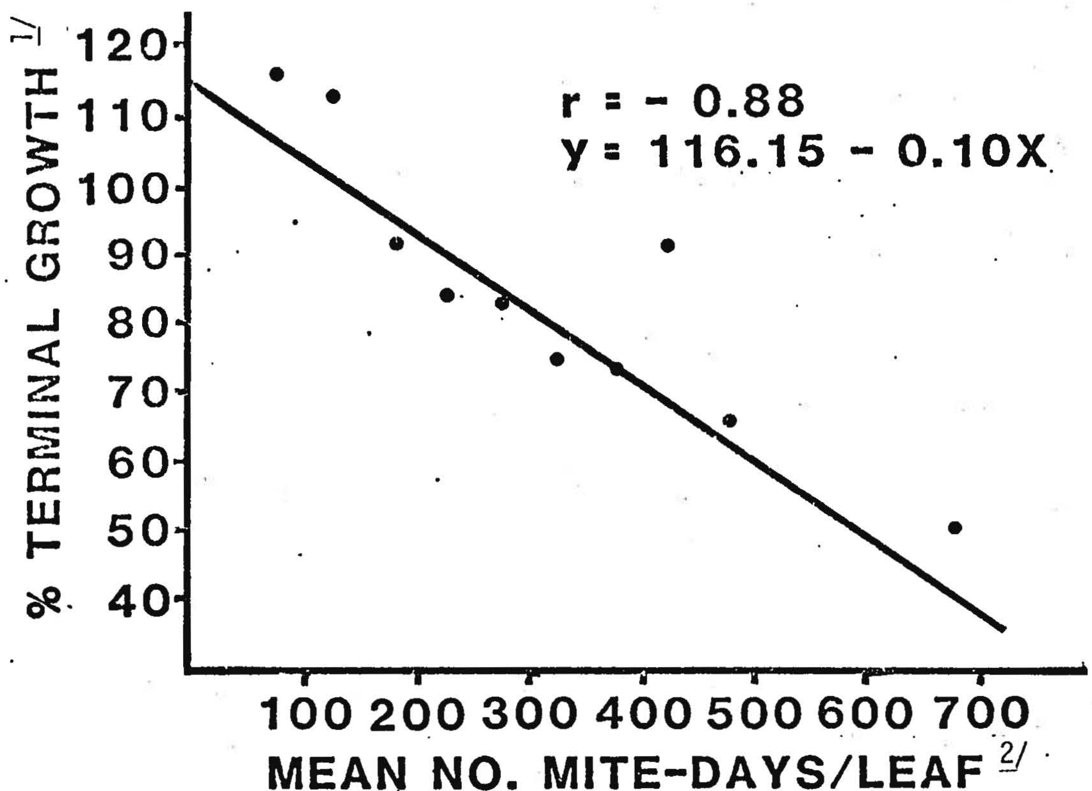

Fig. 3. Relationship of mite-days to percent terminal growth (Laborde, 1980).

1/Mite infested trees are expressed as a percentage of the check tree within the same block.

2/Mite-days per leaf based on categories of 50 mite-day increments.

Table 2. Effects of Varying Levels of Mites on Almond Tree Growth and Productivity in Field Trial, 1979-1980.

Treatment No.	Mite-days/leaf[1]	Terminal growth (cm)[2]	Girth (cm)	Mean leaf size (cm^2)[3]	Yield (lbs)[4]
			1979		
1	16	38.0 A	62.5 A	15.7 A	10.2 A
2	178	32.8 A	58.6 A	15.2 A	11.8 A
3	300	33.2 A	61.2 A	15.4 A	12.0 A
4	424	33.8 A	59.5 A	15.9 A	11.2 A

Treatment No.	Mite-days[1] 1979	Mite-days[1] 1980	Terminal growth (cm)[5]	1979-1980 Change in Girth (cm)	Mean leaf size (cm^2)[3]	1979-1980 % increase in yield/tree[4]
				1980		
1	16.0	0	32.7 A	9.4 A	13.1 A	155.1 A
2	178	0	32.0 A	8.8 A	13.2 A	123.8 AB
3	300	0	25.2 B	8.5 A	13.0 A	120.3 AB
4	424	0	25.2 B	9.1 A	12.6 A	110.8 B

[1] Mean based on 14 replicates
[2] Mean based on 9 terminals
[3] Mean based on 32 leaves
[4] Mean based on 14 trees
[5] Mean based on 18 terminals

percent increase in yield when compared to 1979 yields. The values were calculated for each tree based on the following formula:

$$\frac{\text{1980 yield - 1979 yield}}{\text{1979 yield}} \text{ X } 100\%$$

The expression of the data in this form helped account for the initial variability in tree sizes within the orchard. All test trees experienced an absolute increase in yield, but trees which had been mite-infested failed to increase as much as non-infested trees. Treatment 4 experienced a reduction from 150.1 to 110.8 in percent yield increase (Table 2). This reduction in potential yield increase proved significant at the 0.05 confidence level. Treatments 2 and 3 also showed reductions in percent yield increase from 155.1% to 123.8% and 120.3%.

The experimental orchard represents a very actively growing orchard at a stage of development where dramatic increases in yield may be expected. If a more mature orchard, which was near maximum expected yields, had been selected, then the effects of mite feeding may have been much less severe.

Effects of Mite-days on Almond Tree Photosynthesis and Transpiration, 1978-1979

The examination of the interactions between spider mite feeding and the almond tree's physiological processes was accomplished through the use of a dual isotope porometer, which simultaneously measures a leaf's photosynthetic and transpiration rates. The effects of spider mite feeding on seasonal photosynthetic and transpiration rates have been previously reported in the 1978 and 1979 Almond Board Reports. Understanding the relationships between mite-days and the almond tree's photosynthetic and transpiration rate should help provide a data base for establishing an economic threshold for spider mites on almonds.

The relationship between mite-days and the two physiological processes is expressed in terms of conductance values. Stomatal conductance to H_2O relates directly to the transpiration rate of an almond leaf if the environment were held constant. The expression of the data in terms of stomatal conductance to H_2O rather than the absolute transpiration rate allows the data to be interpreted without the effects of daily fluctuations in temperature or relative humidity. Therefore, the potential transpiration rate declines at the same rate as the stomatal conductance to H_2O.

Similarly, total conductance to CO_2 relates directly to an almond tree's photosynthetic rate. The tree's photosynthetic rate is reduced at the same rate as the total conductance to CO_2 is reduced by increasing mite-days.

Biweekly estimates of the tree's photosynthetic and transpiration rates were made with the dual isotope porometer. Thirty leaves were sampled per tree in order to obtain a mean photosynthetic and transpiration rate. All sides of the tree as well as the upper and lower halves of the tree canopy were equally sampled with the dual isotope porometer.

1979 Porometer Trial

Eight pairs of trees were established within a well irrigated five-year-old orchard in 1979. The orchard will be referred to as test site II.

One tree in each pair was kept mite-free with Omite 30WP, while the other trees' mite population was allowed to develop unchecked. Mite population estimates were made in the same manner as in the 1978 porometer trial.

The dual isotope porometer was used to take 20 samples per tree on a biweekly basis. The tree was sampled equally from all sides of the tree as well as from the upper and lower halves of the tree canopy.

Results

The conductance values of the mite-infested trees are expressed as a percentage of the non-infested tree within the same block. For Figs. 1 and 2 the values included in the regression were taken prior to the decline in the check trees due to water stress.

Fig. 1 represents the relationship between mite-days and total conductance to CO_2 in the water-stressed test site I orchard which was sampled in 1978. The relationship is described by the function $y = 90.4 - 0.05X$ which has a correlation coefficient of $r = -0.90$. At 500 mite-days, the function predicts a 34.6% reduction in the tree's photosynthetic rate.

Fig. 2 depicts the relationship between mite-days and total conductance to CO_2 within the well irrigated orchard sampled in 1979 test site II. A regression line with a correlation coefficient, $r = -0.83$ is determined from the function $y = 96.0 - 0.028X$. At 500 mite-days the regression predicts a reduction of 18% for the tree's photosynthetic rate. The 16.6 percent

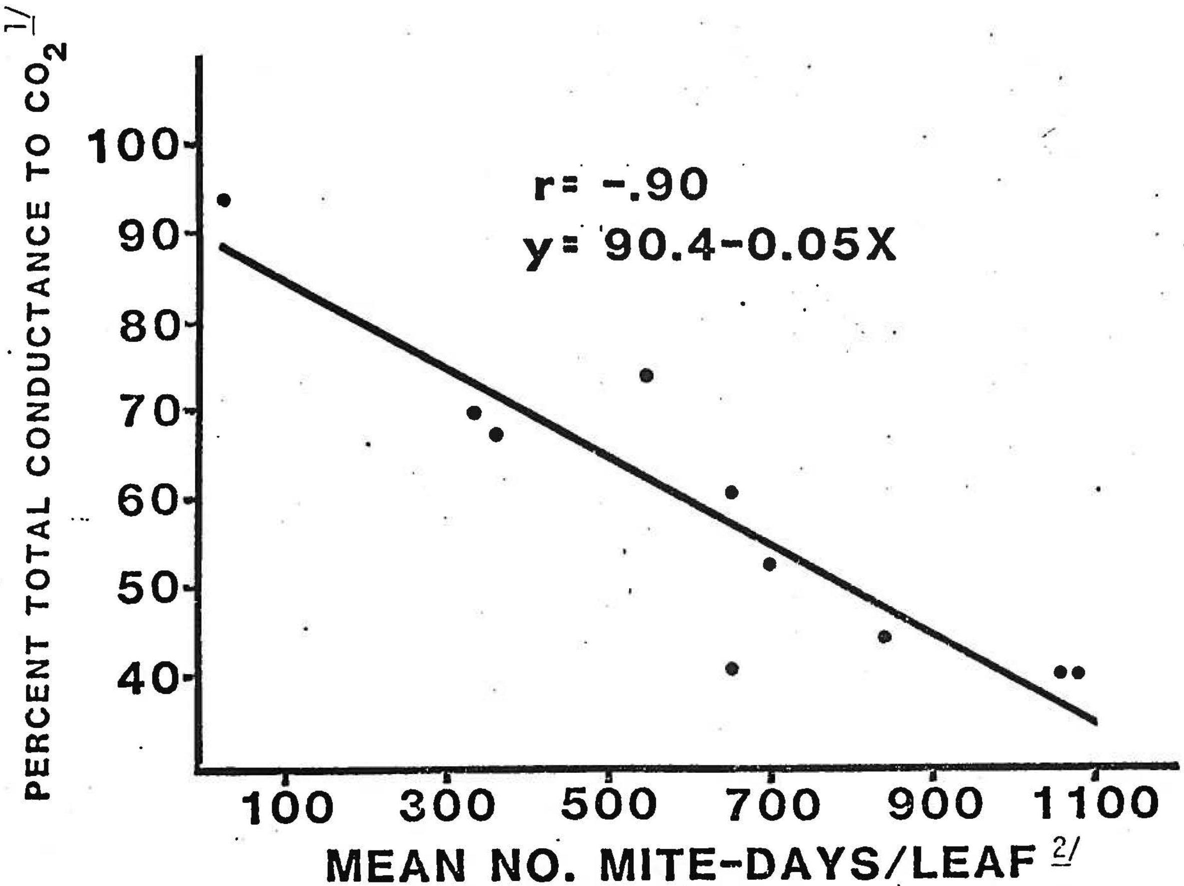

Fig. 1. Relationship of mean number of mite-days per leaf to percent total conductance to CO_2 (Kroeker, 1978).

[1]Total conductance to CO_2, which relates directly to the photosynthetic rate, is expressed as a percentage of the check tree within each pair.

[2]Values included in the regression were sampled prior to Aug. 30, 1978.

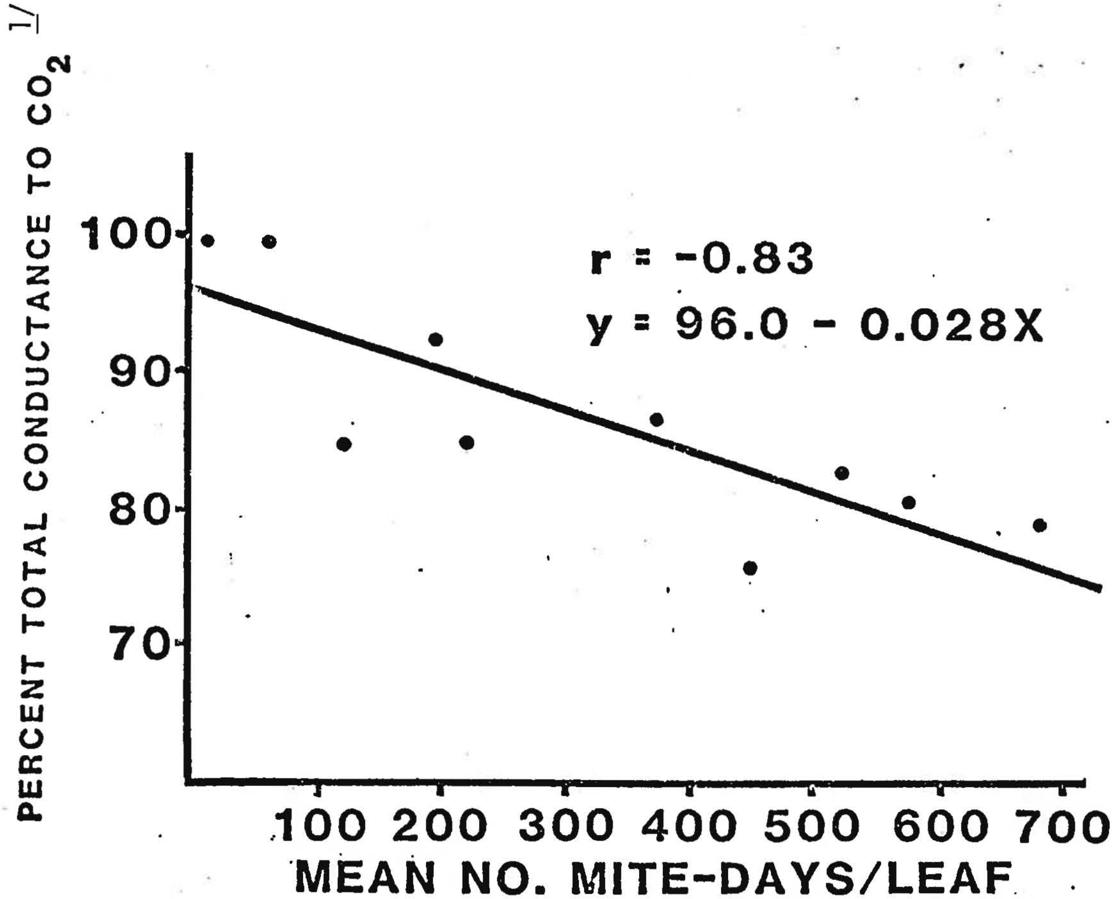

Fig. 2. Relationship of mean number of mite-days per leaf to percent total conductance to CO_2 (Laborde, 1979).

1/ Total conductance to CO_2, which relates directly to the photosynthetic rate, is expressed as a percentage of the check tree within each pair.

difference between the two orchards may be a result of the water stress in test site I. It appears that if an orchard is not maintained under optimum water conditions, then the effects of mite feeding may be significantly increased.

Excellent correlations were obtained between number of mite-days per leaf and percent stomatal conductance to water. In Fig. 3, a regression line, which is described by the function $y = 93.3 - 0.05 X$, has a correlation coefficient of $r = 0.89$, which is indicative of good predictive value. This figure represents the relationship between mite-days and potential transpiration rate within a water stressed orchard. Based upon the regression line, 500 mite-days would result in a 31.7% reduction in the tree's mean stomatal conductance to water.

Fig. 4 expresses the relationship between mite-days and stomatal conductance to water within a well-irrigated orchard. Based upon the function $y = 106.2 - 0.05X$, 500 mite-days results in a 18.6% reduction. Thus, it would appear that if an orchard is water stressed, then the effects of mite-feeding are compounded.

Conclusion

Spider mite feeding is significantly reducing the almond tree's photosynthetic and transpiration rates. The use of mite-days to estimate mite damage appears to provide excellent correlations between spider mite feeding and the subsequent reductions in the tree's physiological processes.

In addition, the differences in response to spider mite feeding between the water stressed and nonstressed orchard may help provide information about the interaction between an orchard's water status and the effects of spider mite feeding. Field observations indicate that orchards subjected to

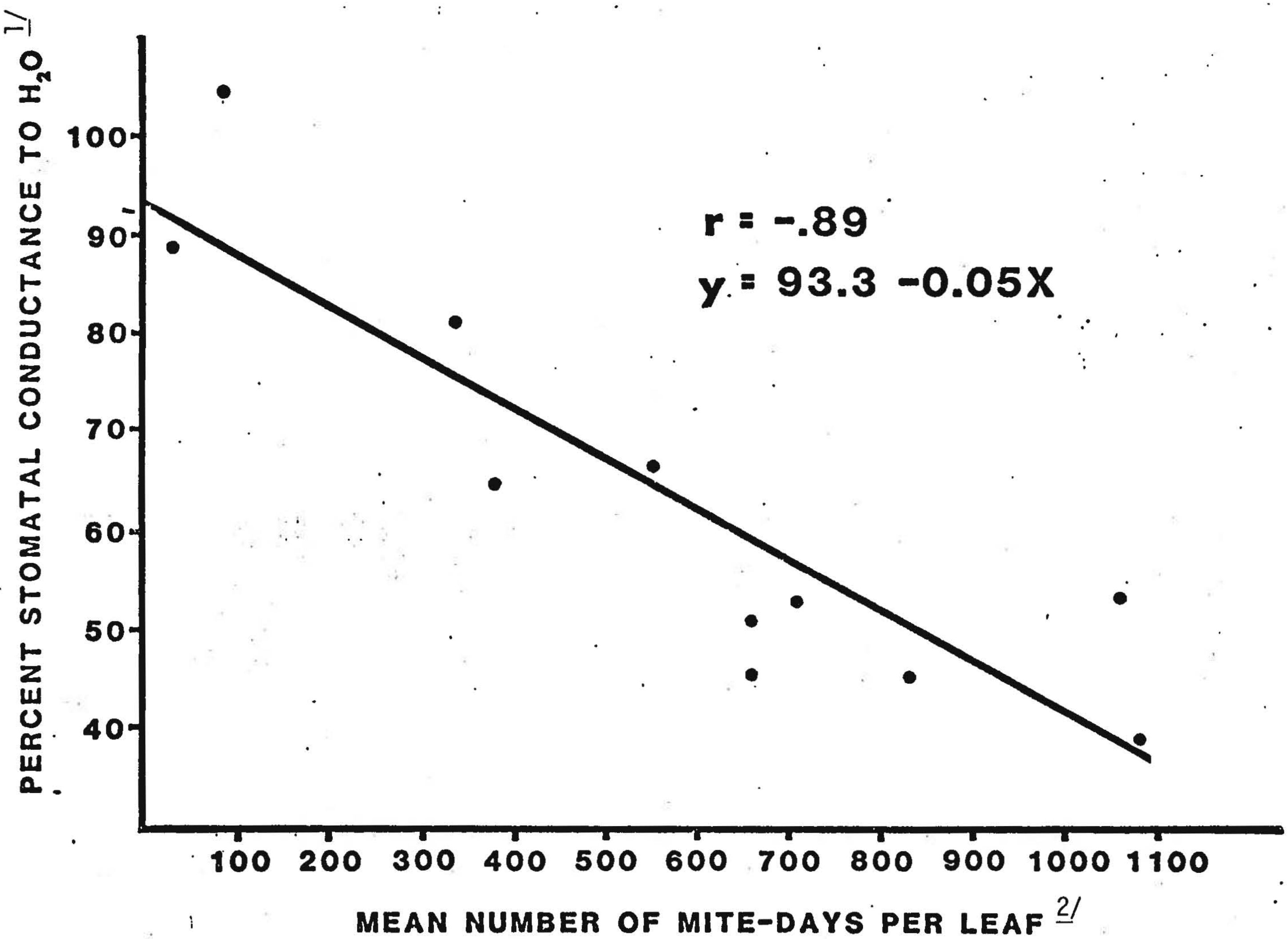

Fig. 3. Relationship of mean number of mite-days per leaf to percent stomatal conductance to H_2O (Kroeker, 1978).

[1]Stomatal conductance to H_2O, which relates directly to transpiration rate at a constant temperature, is expressed as a percentage of the check tree within each pair.

[2]Values included in the regression were sampled prior to Aug. 30, 1978.

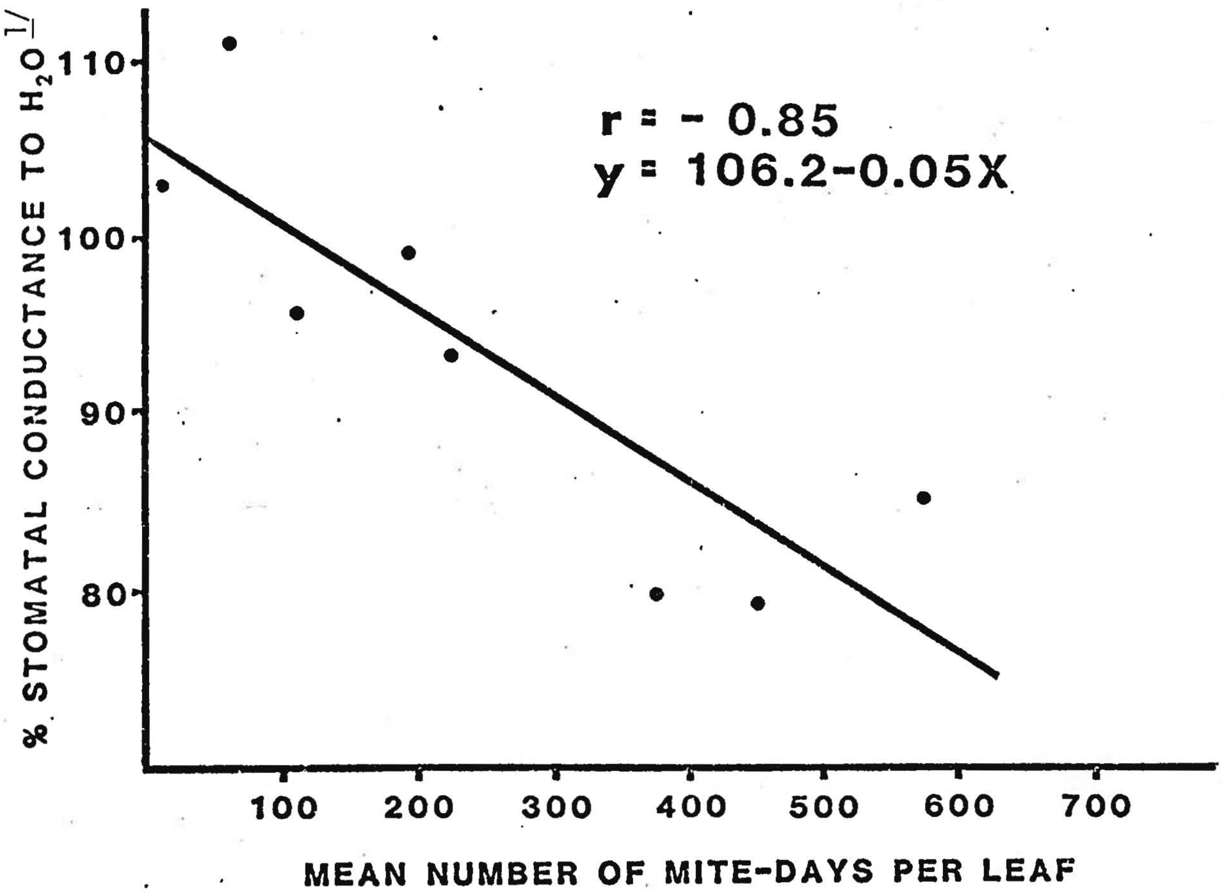

Fig. 4. Relationship of mean number of mite-days per leaf to % stomatal conductance to H_2O (Laborde, 1979).

1/ Stomatal conductance to H_2O which relates directly to transpiration rate at a constant environment, is expressed as a percentage of the check tree within each pair.

water stress will tend to defoliate trees at lower levels of mite damage. The effects of reduced photosynthesis and transpiration by spider mite feeding appear to be compounded by an orchard's water stress.

The implications of these relationships between mite-days and conductance values indicate that proper orchard water management may be necessary to minimize the effects of spider mite feeding. This idea will require further replicated testing in 1981.

Summary

The research over the past three years has provided information in regard to an almond tree's responses to increasing mite damage. Significant reductions in yield, terminal elongation, and leaf size have all been demonstrated, as well as significant reductions in both photosynthesis and transpiration. The relationships between the measured parameters and the different levels of mite-days have provided information which is necessary for determining an economic threshold for spider mites.

The relationships between spider mites and an almond tree constitute only one facet of the information required to develop an economic threshold. Additional data, such as the current almond market situation, must be incorporated in order to develop a meaningful threshold level.