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Project Report 78 - C 2 B

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Project: Navel Orangeworm Research
Control of Mites on Almonds

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Contents

Interpretive Summary

The objectives of the project were to evaluate: a) the predatory mite, Metaseiulus occidentalis, as a control agent for spider mites in southern San Joaquin Valley almond orchards, and b) the potential of the Australian lady beetle, Stethorus loxtoni, as a control agent for spider mites on almonds in California.

Plots were set up in untreated blocks of five almond orchards in the Southern San Joaquin Valley. One was dropped due to insecticidal treatments, but one orchard each near Chowchilla, Bakersfield and Blackwell's Corner was monitored every two weeks from April through September. These three plots were in the Integrated Pest Management Orchards. The 4th orchard was checked periodically. Pest mite species varied from orchard to orchard, but Pacific mites predominated. Other species found included the: two-spotted spider mite, European red spider mite, citrus red spider mite, and "strawberry" mite Tetranychus turkestani. The most important predators found included: M. occidentalis, the green lacewing (Chrysopa carnea),and the six spotted thrips (Scolothrips sexmaculatus). M. occidentalis was established and well distributed in two Pest Management Orchards where they controlled the spider mites. (The other Pest Management Orchard monitored had so few prey mites until the end of the season that no conclusions can be made of the impact of M. occidentalis.) Low-moderate numbers of lacewings and thrips were present and were possibly important early in the season in cleaning up spider mites, but they never responded numerically to spider mite populations.

Releases of Guthion-resistant M. occidentalis into 4 orchards did not yield measurable results because so many native M. occidentalis were present.

About 6,000 S. loxtoni adults were released at 7 sites in the San Joaquin Valley, including 4 almond orchards. Releases were made where insecticide treatments were not planned. Recoveries were made at 4 release sites at least once, and 4 recoveries at one site were made over a two-month interval. Laboratory and field cage tests are now underway to evaluate this species' potential for overwintering in the San Joaquin Valley. We hope that this species can establish permanently in California.

The impact of Sevin on spider mites and M. occidentalis was evaluated at the Blackwell's Corner orchard. Sevin caused dramatic increases in Pacific mites due to mortality of M. occidentalis, although physiological stimulation of the spider mites' reproduction cannot be eliminated as a contributing factor.

Selection for a permethrin-resistant M. occidentalis has yielded promising responses which could prove to be useful under orchard conditions.

I. Introduction, Objectives and Orchard Descriptions

The objectives of this project were to evaluate the potential for establishment of the Australian lady beetle, Stethorus loxtoni, in the Central Valley of California. Also, we sought to evaluate the potential of the spider mite predator, Metaseiulus occidentalis, as a control agent for spider mites in almond orchards. Studies during 1977-78 had shown that M. occidentalis was present in orchards near Modesto and Stockton, but they had little impact on European red mite populations. This predator is effective against the Pacific, two-spotted and "strawberry" spider mites on other crops in California so it was thought that M. occidentalis might be important in almonds as well. In addition we wanted to release Sevin- and Guthion-resistant M. occidentalis to determine if these could be established in almonds.

Orchards Used In the Project: Five orchards were surveyed in April and plots were established. One orchard was discontinued in June due to treatments by the cooperator, but the following 3 orchards were studied in detail throughout the season. Another was checked periodically.

Blackwell's Corner: Work at this orchard was conducted in the 2 check blocks of the IPM block. M. occidentalis releases were made into Nonpareil trees in the red check, and Stethorus loxtoni releases were made into the red and pink check block. Two rows of Nonpareil trees alternated with one row of Merceds. The orchard was sprinkler irrigated about every 2 weeks. The trees were planted in 1966.

PLOT DIAGRAM - BLACKWELL

2 NONPAREIL : 1 MERCED

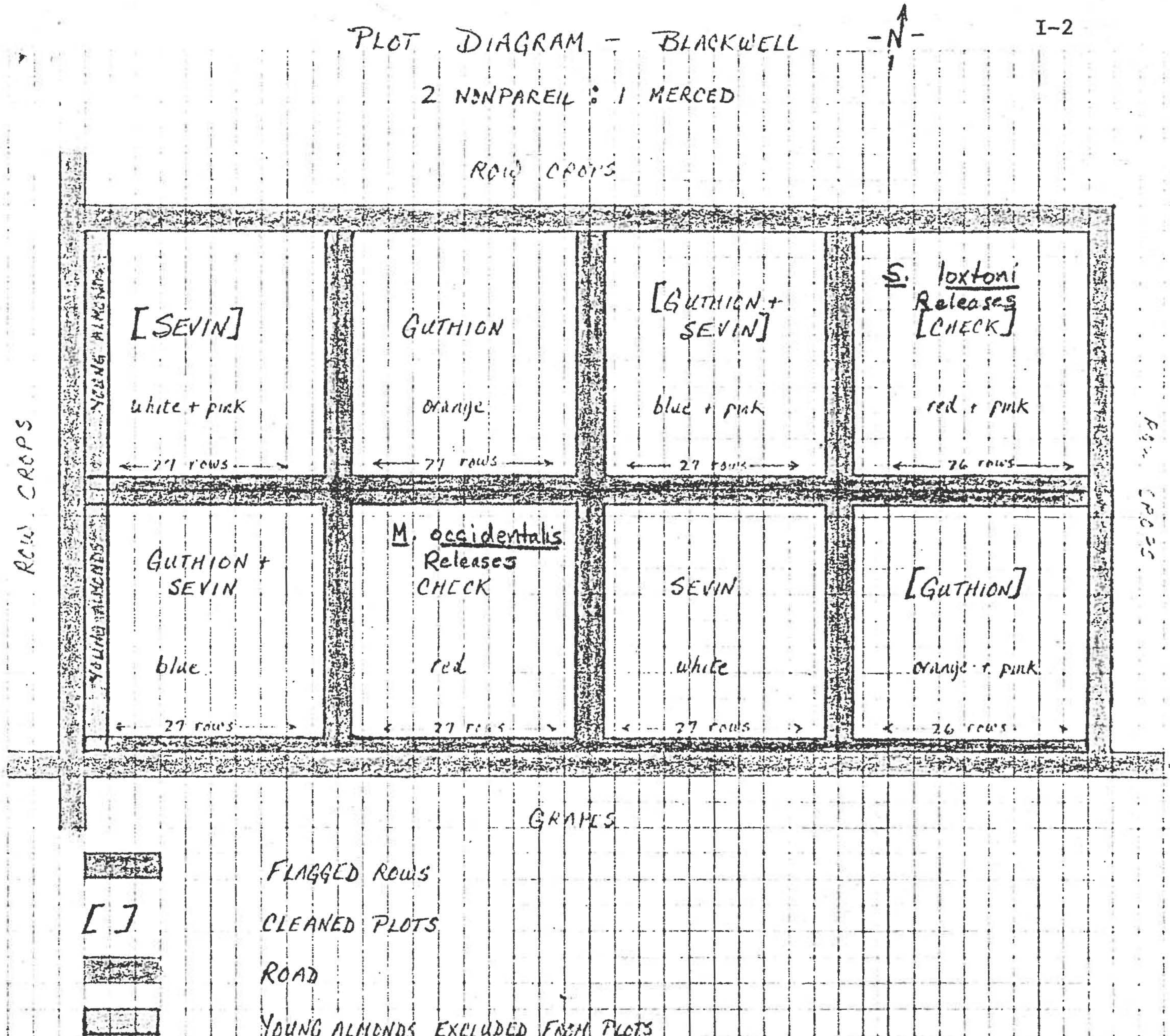


Fig. I-1

PLOT DIAGRAM - Bakersfield (BIDART)

1 MISSION : 2 NONPAREIL : 1 MERCED

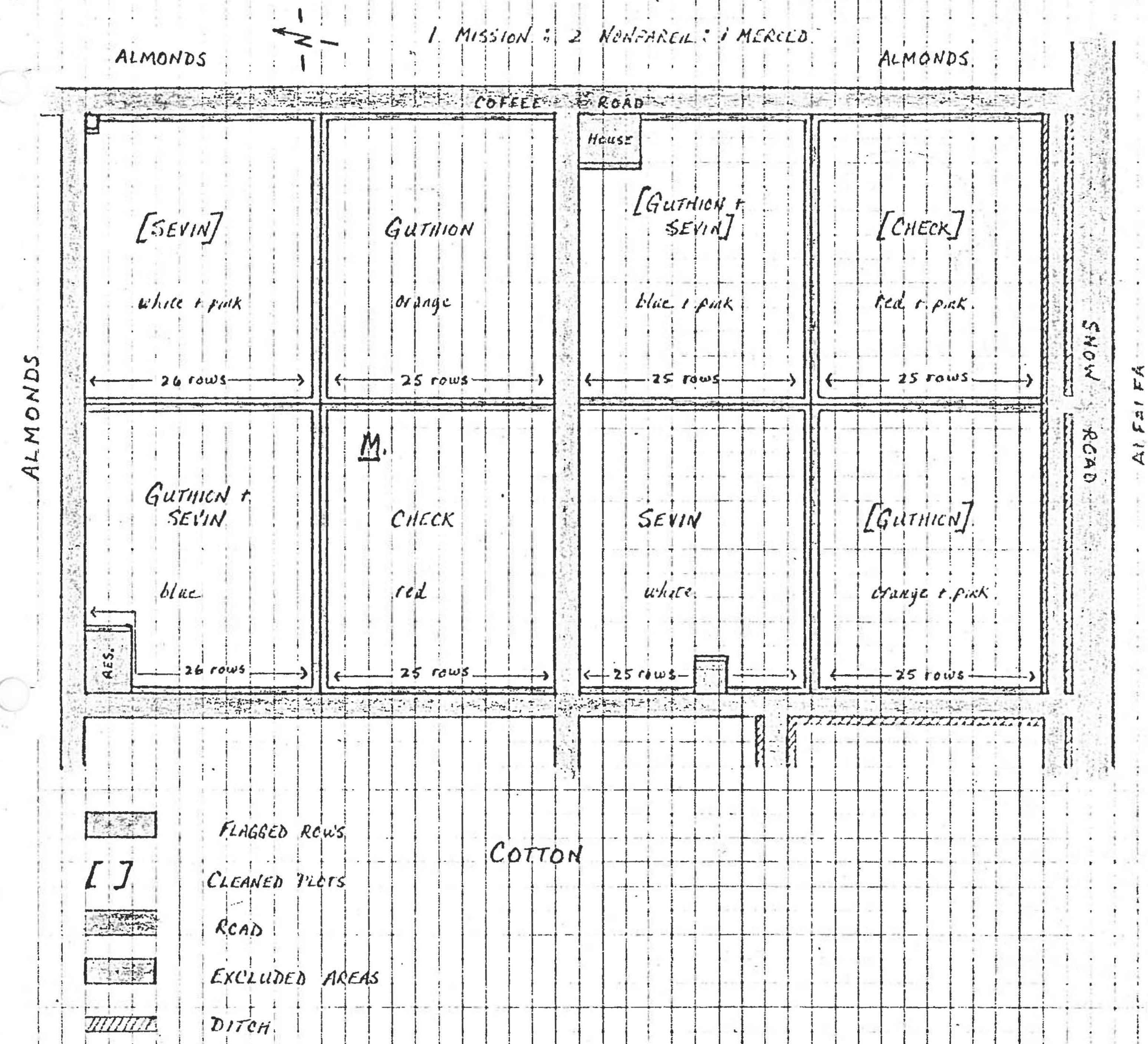


Fig. I-2

No winter sprays were applied during 1977-78. See Fig. I-1 for a Plot diagram.

Chowchilla Orchard: The Chowchilla orchard was 12 - 15 years old, and irrigated with solid set sprinklers. No cover sprays were applied during the winter of 1977-78. Guthion had been applied for N.O.W. in 1977, but no acaricides were applied during 1977. Releases of *M. occidentalis* were made into Nonpareils. NePlus trees were in every 4th row.

Bakersfield Orchard: The trees are 6 years old and flood irrigated with mowed grass centers. No winter sprays were applied during 1977-78, and no N.O.W. treatment was made during 1977. *M. occidentalis* was released into the red check block of the Bakersfield (Bidart) IPM orchard. *Stethorus loxtoni* were released into the white and pink Sevin block. See Fig. I-2 for a Plot diagram.

II. Pest Mites and Predators in Southern San Joaquin Valley Almond Orchards

The species of spider mites found and their relative abundance varied from orchard to orchard. Table II-1 shows the species of spider mites and predators found in the Blackwell's Corner, Bakersfield, and Chowchilla orchards. Their peak relative abundance differs.

Seasonal abundance patterns also varied. *T. pacificus* was the predominant species found early in the season in all orchards and *M. occidentalis* was also found early (Tables II-2, II-3, II-4, and II-5). Citrus red mite was rare in the Blackwell's corner orchard and the Chowchilla orchard but more common in July in the Bakersfield orchard. *T. turkestani* ("strawberry" mite) was never identified in the Blackwell's Corner or Chowchilla orchards but was present at the Bakersfield orchard. The two-spotted spider mite was found in low numbers in all three orchards.

Predators were common in all three orchards throughout the season. The native lady beetle predator of mites, *Stethorus picipes*, was found at the Blackwell's Corner and Chowchilla orchards only. Lacewings and six-spotted thrips (*Scolothrips sexmaculatus*) were also present throughout the season in low numbers in the untreated blocks of these orchards. Phytoseiids other than *M. occidentalis* were present in all three orchards, but in low numbers only. *M. occidentalis* numbers became abundant in the Blackwell's Corner, Bakersfield and

Table II-1. Maximum Mean Per Leaf of Predators and Spider Mites in Almond Orchards in 1978

	Spider mites[a]				Predators[b]					
Orchard	*T. pacificus*	*T. urticae*	*T. turkestani*	*P. citri*	*M. occidentalis*	Other phytoseiids	Thrips	Lacewings	Spiders	*S. picipes*
Blackwell's corner	++++	+	0	+	++++	+	+	+	+	+
Bakersfield	++	+	++	++	++	+	+	+	0	0
Chowchilla	+++++	+	0	+	++	+	+	+	+	+

[a] Spider mites: 0 = none, + = .001-.5, ++ = .5-5, +++ = 5-10, ++++ = 10-50, +++++ = 50 +

[b] Predators: 0 = none, + = .001-.05, ++ = .05-.5, +++ = .5-1, ++++ = 1-5

Table II-2. Seasonal Abundance of Spider Mites and Predators in the Blackwell's Corner Almond Orchard, 1978

Sample Date	Spider mites[a]				Predators[b]				
	T. pacificus	*T. urticae*	*T. turkestani*	*P. citri*	*M. occidentalis*	Other phytoseiids	Thrips	Lacewings	*S. picipes*
April 27	+	0	0	0	0	0	0	0	0
May 8	+	0	0	0	+	+	+	0	0
23	+	0	0	0	+	+	+	0	0
June 8	+	0	0	+	0	+	+	0	0
22	++++	0	0	+	++	+	+	+	+
July 6	++++	0	0	+	++++	+	+	0	+
18	++	0	0	+	++	+	+	0	+
August 1	++++	+	0	+	++++	+	+	+	+
9	++++	0	0	0	++++	+	+	+	+
23	+	+	0	+	++	+	+	0	+
September 7	+	0	0	+	+	0	0	+	+

[a] Mean Spider Mites Per Leaf
0 = none
+ = .001 - .5
++ = .5 - 5
+++ = 5 - 10
++++ = 10 - 50

[b] Mean Predators per Leaf
0 = none
+ = .001 - .05
++ = .05 - .5
+++ = .5 - 1
++++ = 1 - 5

Table II-3. Seasonal Abundance of Spider Mites and Predators in the Bakersfield IPM Almond Orchard, 1978.

Sample Date	Spider mites[a]				Predators[b]				
	T. pacificus	T. urticae	T. turkestani	P. citri	M. occidentalis	Other phytoseiids	Thrips	Lacewings	S. picipes
April 27	+[c]	+[c]	+[c]	0	0	0	+	0	0
May 8	+[c]	+[c]	+[c]	0	+	0	+	+	0
22	+[c]	+[c]	+[c]	0	+	0	+	0	0
June 8	+[d]	-	-	0	+	0	+	+	0
21	+[d]	-	-	+	+	+	+	+	0
July 5	++	-	-	+	+	+	+	+	0
17	++	+	-	++	++	+	+	+	0
August 3	++	+	++	+	++	0	+	+	0
9	++	0	++	+	++	+	0	+	0
28	+	+	0	+	+	0	+	0	0
September 19	+	+	0	+	+	+	+	+	0

[a] Mean Spider Mites Per Leaf
0 = none
+ = .001 - .5
++ = .5 - 5

[b] Mean Predators Per Leaf
0 - none
+ = .001 - .05
++ = .05 - .5

[c] T. spp. only; no adults seen or mounted

[d] Based on adult females

Table II-4. Seasonal Abundance of Spider Mites and Predators in the Chowchilla Almond Orchard, 1978.

Sample Date	Spider mites[a]				Predators[b]					
	T. pacificus	T. urticae	T. turkestani	P. citri	M. occidentalis	Other phytoseiids	Thrips	Lacewings	S. picipes	Spiders
April 10	+	+[c]	0	0	0	0	0	0	0	0
May 5	+[d]	+[d]	0	0	+	0	+	0	0	0
23	+[c]	-	0	0	+		+	+	0	+
June 2	+[d]	-	0	0	0	0	+	+	+	+
15	0	0	0	+	0	0	+	0	+	+
29	+[d]	0	0	0	0	0	+	+	0	0
July 13	+[c]	0	0	0	+	+	+	0	0	0
27	0	0	0	0	0	0	+	0	0	0
August 10	+[d]	+[d]	0	0	+	0	0	0	0	0
25	+++++	+	0	0	++	+	+	0	0	0

[a] Mean Spider Mites Per Leaf
0 = none
+ = .001 - .5
++ = .5 - 5
+++ = 5 - 10
++++ = 10 - 50
+++++ = 50

[b] Mean Predators Per Leaf
0 = none
+ = .001 - .05
++ = .05 -.5
+++ = .5 - 1
++++ = 1 - 5

[c] T. spp. only; no adults seen or mounted.

[d] Based on adult females.

Table II-5. Numbers of Spider Mite Males Mounted and Identified in 1978 for Species Identification

Orchard	Date	*T. pacificus*	*T. turkestani*	*T. urticae*
Blackwell's Corner	June 22	2	0	0
	July 6	6	0	0
	18	3	0	0
	August 1	11	0	0
	9	10	0	0
	23	3	0	4
	Sept.8	1	0	0
Bakersfield	June 21	1	0	0
	July 5	1	0	1
	17	2	0	0
	August 3	5	7	2
	9	2	4	0
	28	3	0	5
	Sept. 19	4	0	5
Chowchilla	Apr. 19	3	0	0
	Aug. 25	16	0	2

Chowchilla orchards as prey abundance increased. Thus, M. occidentalis appears to be the only predator which is responding numerically to prey increases, while the other species appear to be serving as general predators only. (See Section IV for additional data on the regulatory role of M. occidentalis.)

In Chowchilla, spider mite numbers in the M. occidentalis release plot (Table II-4) were so low until the very end of the season that the predator releases did not produce useful data. However, in August a spell of very hot weather, and an apparent "blow-in" of spider mites from "hot spots" elsewhere in the orchard caused a dramatic upswing in Pacific mite numbers. This increase in spider mites was probably accentuated by some plugged sprinklers which meant that some trees were severely water stressed at that time.

III. Releases of *Metaseiulus occidentalis*

Guthion-resistant *M. occidentalis* were released into four orchards: Blackwell's Corner, Bakersfield, Chowchilla and another orchard near Bakersfield. These releases were made as soon as we judged that sufficient prey were present to sustain the predators (Table III-1). Adult females were released into six trees at a high rate and into six trees at a low rate. Six check trees were also monitored. Leaf samples consisted of 30 leaves collected "randomly" from each tree. In the Blackwell's Corner and Chowchilla orchards, where the trees were sprinkler irrigated, small branches were pruned out of the tree crotches. Then, samples were taken while the collector stood in the crotch and pulled leaves off as far up as he/she could reach in order to sample above the level where the leaves were wet by the sprinklers. Leaves were refrigerated and counted under a dissecting microscope. All stages of mites were counted, and graphs show TOTALS of all stages.

Comparisons of the numbers of *T. pacificus* in the check and release trees in both the Bakersfield or Blackwell's Corner orchards were not statistically different, using a Kruskal-Wallis test.

Numbers of *M. occidentalis* in the check and release trees in both orchards were not different either. Thus, I conclude that, relative to the numbers of *M. occidentalis* already present, the predator releases made no measurable impact.

However, the data clearly show that *M. occidentalis* can regulate numbers of spider mites in both the Bakersfield and Blackwell's Corner orchards (Fig. III-1, III-2). In Fig. III-1, the mean numbers of

T. pacificus and M. occidentalis are graphed using the data from all 18 trees. There is a good response by M. occidentalis to Pacific mite increases. In the Bakersfield orchard (Fig. III-2), M. occidentalis responded well to an array of pest spider mites. The mite densities in this orchard probably were not of economic importance, and leaf damage was not noticeable.

In the Blackwell's C orner orchard spider mite densities were higher (Fig. III-1) and produced noticeable stippling on many of the leaves. No defoliation or noticeable webbing occurred, however. The Blackwell's C orner Farm entomologist did not feel that the mite densities warranted treatment with an acaricide. Thus, it appears that in UNTREATED almond orchards where M. occidentalis is present and well distributed that this predator can keep spider mites below the treatment level. However, where insecticides are applied, another story may emerge (see Section IV).

In both the Blackwell's Corner and Bakersfield orchards, we found many M. occidentalis, some six-spotted thrips, and some green lacewings on the leaves in April when the plots were set up. At this time, T. pacificus females were present and ovipositing, especially on the leaves in the crotch of the tree, where I selectively sampled. On the next sample date, when leaves were "randomly" sampled, M. occidentalis, six-spotted thrips and Pacific mites were very scarce, and remained so until late June in both orchards. These observations led me to conclude that M. occidentalis overwinters in these almond orchards and that it, in combination with the six-spotted thrips and lacewings, was very effective in cleaning up early spring spider mite populations.

Table III-1. Releases of Guthion-Resistant *M. occidentalis* during 1978

IPM Orchard	Release Date(s)		*M. occidentalis* per tree released LOW	HIGH
Blackwell's Corner	June 8		250*	250*
	22		100	500
		Total	350	750
Bakersfield	June 8		250*	250*
	July 13		100	500
		Total	350	750
Chowchilla	June 14		300**	-

* Numbers actually released may have been lower due to escape of predators from straws during transit to orchard.

** Very few prey mites were present in this orchard until the end of August, so establishment might not have occurred.

Fig. III-1. Mean numbers of mites per leaf counting all stages in the untreated block at Blackwell's Corner orchard in 1978. The numbers of M. occidentalis are multiplied by ten.

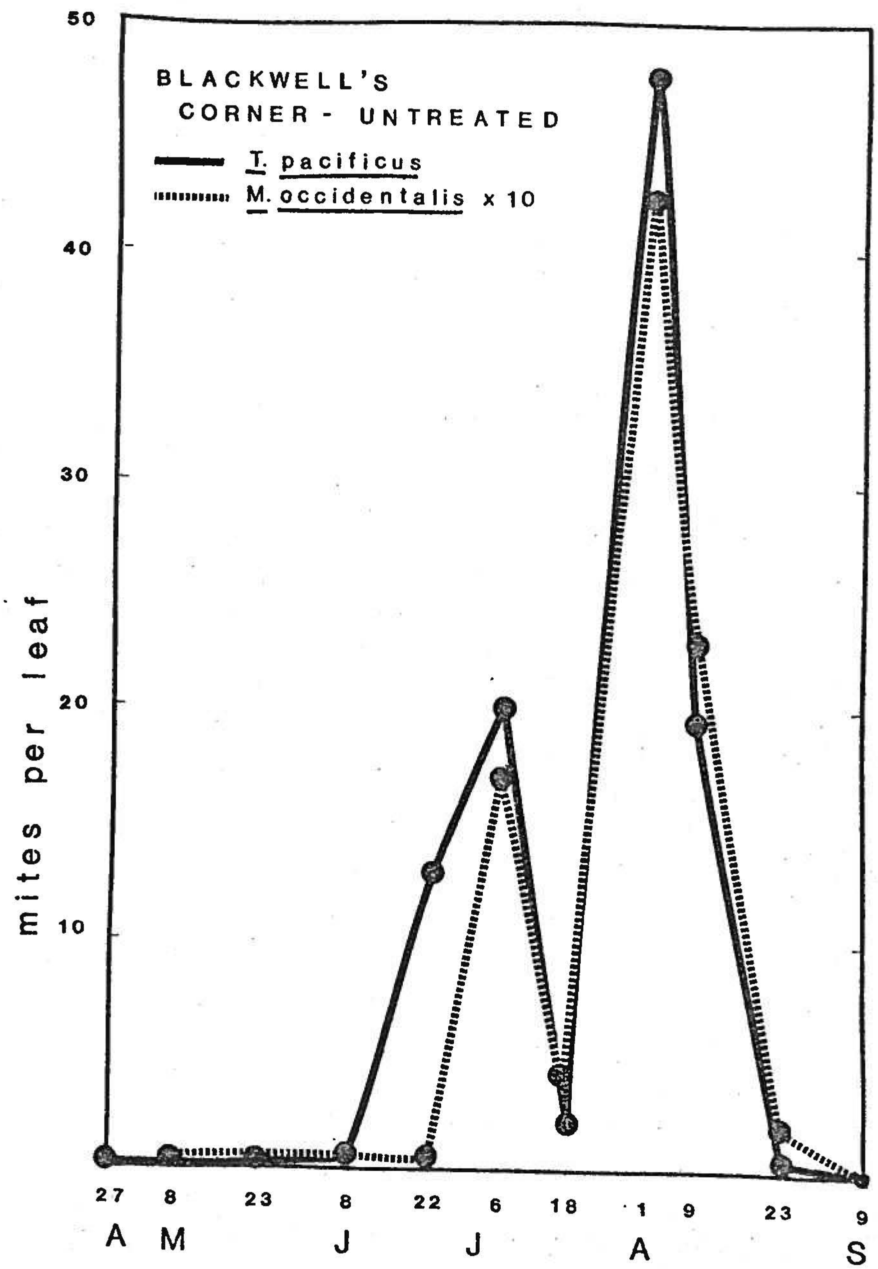
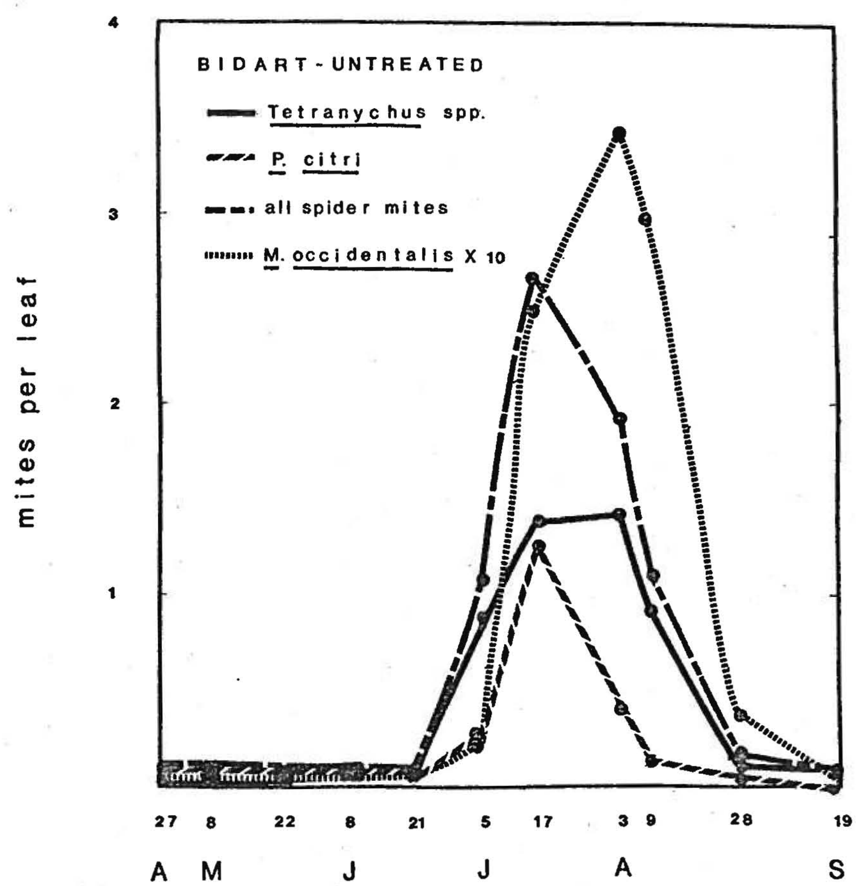


Fig. III-2. Mean numbers of mites per leaf counting all stages in the untreated block of the Bakersfield orchard (Bidart). The numbers of M. occidentalis are multiplied by ten.



IV. Impact of Sevin® on Spider Mites and *M. occidentalis*.

An experiment was set up at the Blackwell's Corner orchard to test a strain of *Metaseiulus occidentalis* selected for its resistance to carbaryl (Sevin®). Unfortunately, the Pacific spider mite (prey) populations were too low to make any useful assessments of the laboratory-selected resistant strain. The experiment did, however, provide a compelling example of the effects of carbaryl on spider mite populations.

Six trees in a carbaryl treated block were compared to six trees in an untreated block. Fifty leaves were sampled from the area above the crotch of each tree, refrigerated, and all stages of both predators and prey were counted. Figures IV-1 and IV-2 document the results. The carbaryl treatment suppressed predator populations (IV-2), although they later responded to the high spider mite populations. The rapid increase in predator population two weeks after the treatment may be due in part to the dispersal of the predators (presumably due to windblown females) from the adjacent untreated plot 3 rows away. This presumption is supported by the very rapid increase in predator numbers and by the fact that the predators collected and evaluated in the laboratory after the Sevin treatment were not resistant to Sevin. The rapid increase in spider mite populations may be due to the loss of predators, to direct or indirect chemical effects which increase the reproductive rate of the spider mites, or to a combination of both factors.

Fig. IV-1. Mean mites per leaf (all stages) in the Blackwell's Corner Sevin Block of the IPM orchard, 1978. Numbers of *M. occidentalis* are multiplied by 10. No Sevin was applied to these 6 trees.

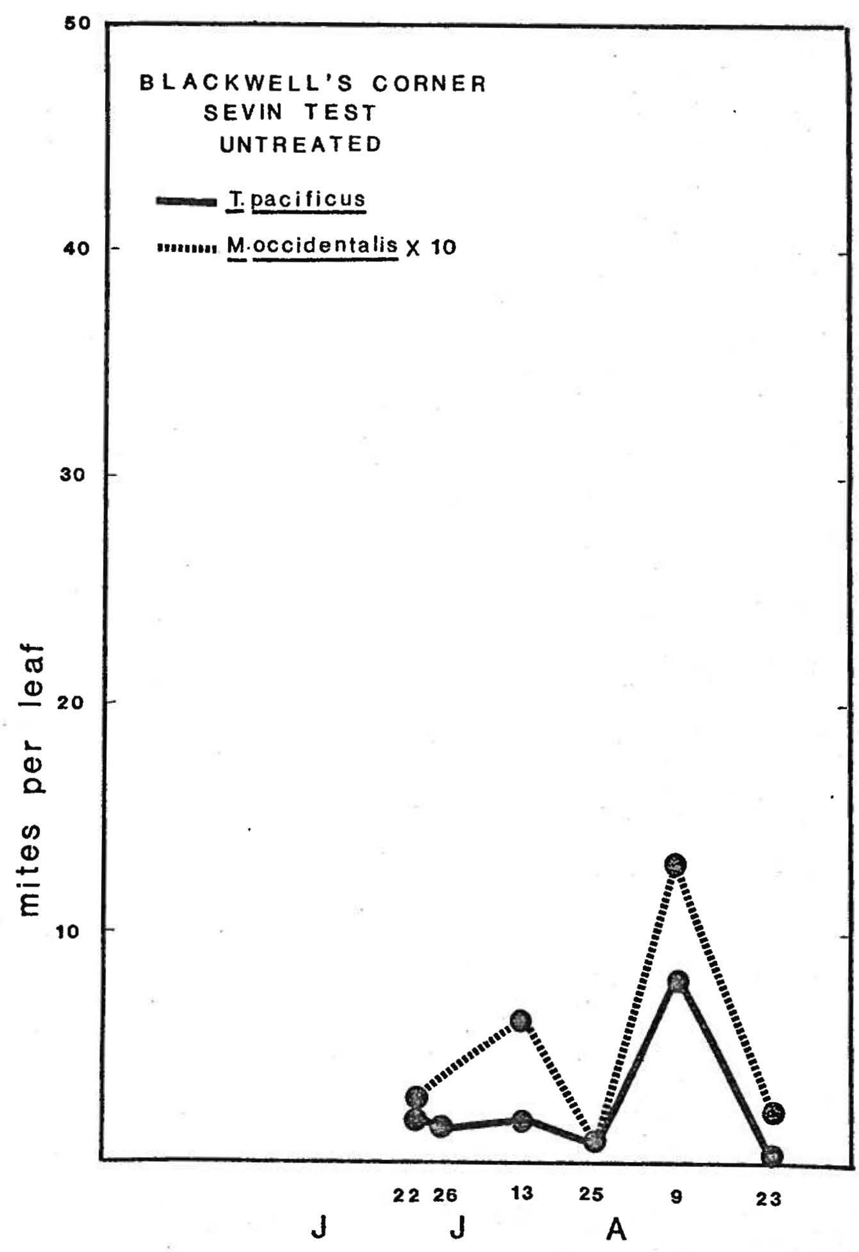
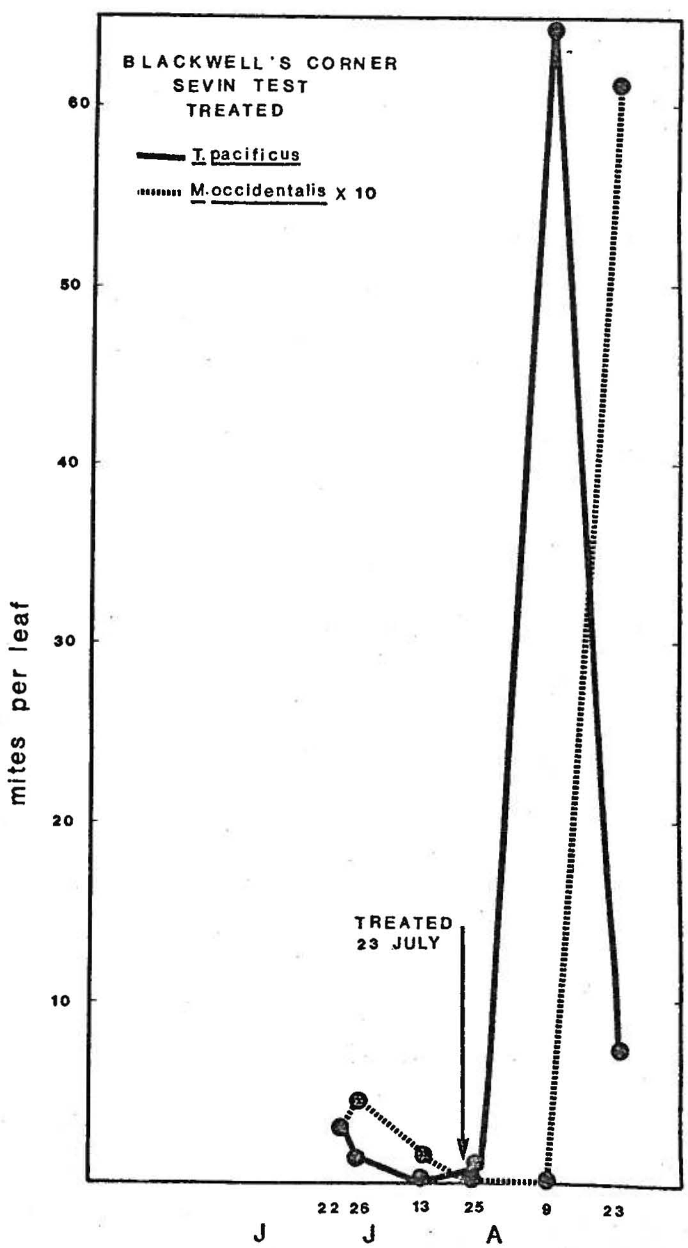


Fig. IV-2. Mean mites per leaf (all stages) in the Sevin-treated block, Blackwell's Corner IPM Orchard, 1978. Numbers of M. occidentalis are multiplied by 10. No acaricide was applied with the Sevin.



V. Irrigation Practices and Spider Mite Abundance and Sampling

During 1978, two observations were made that are included here because they may be of general interest. First, we found that sprinkler irrigation systems vary in the height the spray hits the trees. This is now quite obvious, but my previous experiences had not made this fact so emphatic. Therefore, we had to climb into the crotch of the trees to sample for mites. It was clear that the sprinklers removed or killed spider mites in the lower portion of these trees. Therefore, we will be more careful to determine very early in the season just how high the sprinklers are set.

Secondly we observed a very dramatic effect of poor irrigation upon spider mite populations and impact. In the Chowchilla IPM orchard, a number of sprinkler heads became plugged. This happened in July after a long heat spell and the combination of heat and poor watering allowed dramatic increases in Pacific spider mite densities and impact. Trees side by side varied in their water supply, but probably not in their spider mite populations. The poorly-watered trees became defoliated while the well-watered trees suffered less damage. Clearly, a pest management program must consider the impact of irrigation timing and amounts. This is not a new observation, I realize, but it was a very dramatic one for me.

VI. Studies with Stethorus loxtoni from Australia

Releases -- Table VI-1 lists the sites, numbers released and the recovery records for the S. loxtoni releases. Recoveries were made at 4 sites at least once, and at one site on 4 dates. These sites will be checked in the spring-summer of 1979 to determine if the beetles can be recovered.

Pesticide Susceptibility of S. loxtoni -- Contact toxicity of a number of pesticides had been determined by Walters (1976) for several Stethorus species including S. loxtoni (J. Australian Entomological Society 15:49-52. His results are partially recorded in Table VI-2. We evaluated the toxicity of the synthetic pyrethroid, permethrin, using methods similar to Walters (1976). The results showed a high degree of susceptibility in the adults. An LD_{50} of 0.48 g AI/100 1 permethrin (95% confidence interval = .29-.79) was calculated. This is significantly lower than field doses (1.2 - 12 g AI/100 1) now being tested. At doses of 1 g and 2 g, survivors were severely affected and usually died a few days after the test even though they had been removed from the treated leaf discs.

Overwintering Tests with S. loxtoni -- Three experiments have been designed to evaluate the possibility that S. loxtoni has a diapause or can otherwise survive winter conditions that exist in California's Central Valley. The climate of the area from which the beetles were collected in Southern Australia (near Roseworthy) in 1978 is similar to the Central Valley climate.

One experiment involves rearing S. loxtoni at a constant 8 hour daylength at 19°C to determine if adult females have a reproductive diapause after one or more generations.

The second test involves rearing *S. loxtoni* in field cages located at Berkeley. Reproductive diapause will be looked for in females reared outdoors by removing samples regularly throughout the winter and holding them individually to determine if they are ovipositing when abundant prey is present. Dissections may also be done to ascertain if females are in reproductive diapause. The outdoor cages provide decreasing daylengths and cyclic temperatures.

Finally, we have programmed a growth chamber to mimic the weather data obtained from the U.C. weather station located at Parlier. The temperatures will cycle and daylengths will be decreased or increased by 15 minute increments, as appropriate. Conditions will attempt to duplicate the September to February weather records.

Table VI-1. Releases of S. loxtoni during 1978 in the San Joaquin Valley

Site & Crop	Date(s) Released	Nos. Released	Date(s) Recovered
Dinuba peaches	June 3	1,400	June 15
			July 12
			July 27
			August 8
			August 25
Chowchilla IPM almond orchard	June 14	500	August 8
	July 12	500	
	August 25	400	
Blackwell's Corner IPM almond orchard	June 22	450	July 25
	July 13	500	
	August 23	300	
Clement's almond orchard	June 22	300	none
Bakersfield IPM almond orchard	June 22	160	none
Dinuba, poplars	July 25	500	August 9
Kearney Field Station, Parlier alfalfa	August 8	400	none
	25	500	

Table VI-2. Percentage mortality of eggs, larvae, and adults of *S. loxtoni* to insecticides*

Material	Concentration (%)	Percentage Mortality		
		Eggs	Larvae 24 hrs	Adults 48 hrs
Guthion	0.05	70	100	100
Sevin	0.1	40	100	100
DDT	0.1	100	100	100
Cygon	0.06	0	0	5

* Taken from Walters (1976).

Acknowledgements

R. T. Roush, N. Knop and M. Wilson provided assistance during the project. Katherine Smith faithfully conducted mite counts, assisted in data analysis and carefully reared *S. loxtoni*. We are indebted to Clancy Davis and Wilbur Reil for their cooperation and assistance and the help of Toynette Johnson and Les Barclay in the collections of leaf samples. We value the cooperation of the growers who made their orchards available for study.

Publications

California Agriculture - May 1978

Impact of NOW insecticides on mites in northern California almonds. M. A. Hoy, N. W. Ross and D. Rough (Enclosed).