Project Report 81 - C5:

Control of Mites on Almonds

December 1981

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Contents

I Interpretive Summary

Pesticide-resistant M. occidentalis were successfully mass reared using two methods; a greenhouse technique and a field plot method. The greenhouse production method used 325 square feet of bench space to produce about 1,356,000 Sevin resistant predators during June to September while 170 square feet of bench space was required to produce about 227,000 permethrin resistant predators. The Sevin resistant strain was released into about 210 acres; the permethrin resistant strain was released into about 86 acres. The half acre San Joaquin Valley soybean plot was more efficient than the greenhouse method, although predators could not be harvested from that plot until August. However, by August 6, at least 61 MILLION resistant predators had been produced.

Predators were released after Sevin or permethrin applications were made so the susceptible native predators were greatly reduced. The bean plants were cut and placed in the crotch of the tree; usually in every third tree, in every third row. Such releases were made quickly if a small 3 wheeled cart or pickup truck could be driven down the row. Release and nonrelease trees in all orchards were banded in order to determine if the resistant predators are overwintering successfully; predators from the bands will be recovered and tested during the winter.

The resistant predators established in the orchards and spread in several was spectacular. In one orchard near Livingston, we obtained evidence that the predators were spreading through air currents. The predators spread within a few weeks to nonrelease trees and we also trapped predators in large numbers during July and August on sticky panels outside

the orchard downwind from the prevailing winds. We now wonder if the resistant predators will spread from our release sites to surrounding almond orchards.

Low rates of Omite and Plictran were used to manage spider mites in several of the release orchards. These low rates are promising pest management tools, but can be less effective than desired sometimes. Their use requires adequate monitoring of spider mite densities, and the presence of adequate numbers of predators in the orchard. If it is quite hot, the orchard is water stressed, and if spider mites are already dense so there is abundant webbing, then low rates may be ineffective in preventing foliage damage.

A small mite (Pyemotes) was released into 2 almond orchards to control southern red fire ants. The results of the releases will be evaluated in the spring of 1982.

II Introduction

The project objectives for 1981-82 were:

1) Release Sevin- and permethrin-resistant *M. occidentalis* into almond orchards, to compare results when predators are released by helicopter and by ground (every fifth tree every row). We expect to release into 2-10 almond orchards. The 1st year we will evaluate predator establishment and dispersal; the 2nd year we will evaluate overwintering and efficacy of the resistant strains. We will evaluate dispersal of the resistant strains throughout large (80-100 acre) blocks and into adjacent orchards. 2) Continue evaluation of Omite rates as a mite management tool. 3) Evaluate a mite as a parasite of southern red fire ants, pests of nuts in almond orchards in the southern San Joaquin Valley. 4) Serve as an advisor on mite problems for extension personnel.

This report includes data in manuscript form that has been, or will be, submitted for publication.

Two Methods for Large Scale Production of Pesticide-Resistant Strains of the Spider Mite Predator *Metaseiulus occidentalis* (Nesbitt) (Acarina: Phytoseiidae)

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Abstract

Two methods of rearing pesticide-resistant strains of *Metaseiulus occidentalis* are described. Over 1.5 million predators were reared on pinto bean plants in 45.5 square meters of greenhouse bench space between June and September. About 62 million predators were reared in a 0.2 hectare soybean field plot. Inputs of labor and predator yields are compared, as are other advantages and disadvantages of the two methods.

1. Introduction

A genetic improvement program with the spider mite predator, Metaseiulus (=Typhlodromus or Galendromus) occidentalis (Nesbitt) has produced strains that are resistant to carbaryl and permethrin in addition to their original organophosphorus (OP) insecticide resistance (Roush and Hoy 1981a; Hoy and Knop 1981). Evaluations of the laboratory-selected strains have been conducted in the laboratory, greenhouse, and in small field plots in apple, pear and almond orchards (Roush and Hoy 1981b; Hoy et al., 1980; Hoy, Westigard and Hoyt, In prep.). Because the resistant predator strains established, survived the appropriate pesticide applications, overwintered, and spread from release to nonrelease trees, the resistant predator strains were released into approximately 120 hectares of almond orchards in the San Joaquin Valley in California during 1981 as part of a large scale implementation project (Hoy et al.,1982.). Such releases required large numbers of predators.

Most previous rearing methods developed for phytoseiids are suited for laboratory or modest insectary rearing programs (Ristich 1956; Furr and Shaw 1977; Theaker and Tonks 1977; McMurtry and Scriven 1965; Scriven and McMurtry 1971), although Field et al.(1979) described 2 rearing methods using apple trees and soybeans to mass produce an OP-resistant strain of M.occidentalis for Australian apple and peach orchards.

We report 2 methods, highly efficient and inexpensive, that allowed us to produce over 62 million carbaryl-OP-resistant M.occidentalis in a 0.2 hectare soybean plot and over 1.5 million sulfur-OP, permethrin-OP, or carbaryl-OP-resistant M.occidentalis in the greenhouse using a total of 45.5 square meters of bench space during June, July and August. Since this phytoseiid species does not feed on pollen, the two-spotted spider mite, Tetranychus urticae (Koch) was mass reared as prey. Advantages and disadvantages of the two methods are compared.

2. Materials and Methods

Greenhouse rearing

Rearing in the University of California, Berkeley, greenhouse had three goals, producing "pure" colonies of spider mites for feeding laboratory colonies, augmenting prey populations in the greenhouse predator rearing system, and producing pesticide-resistant predator strains for field releases. The 3 predator strains reared are resistant to carbaryl-OP, (Roush and Hoy 1981a), permethrin-OP (Hoy and Knop 1981), and to sulfur-OP insecticides (Hoy and Standow 1981). Carbaryl, OP, and sulfur resistances are determined by single major semidominant genes (Hoy and Standow 1981; Roush and Hoy 1981a; Hoy, Unpubl.). The permethrin resistance is determined polygenically (Hoy and Knop 1981).

Pinto beans, _Phaseolus vulgaris_ (L), were obtained in bulk from a grocery store and grown in a mixture of sterilized U.C. soil mix and vermiculite (1:1) in 35 X 28 X 55 cm flats. Seeds (ca.125) were planted about 1 cm deep in the soil mix and watered with Captan (1.8 gram 50 WP/liter water) to control diseases. The bean flats were fertilized by adding 25 grams 5-10-10 granular fertilizer upon planting.

When the primary leaves were 2-4 days old, leaves from stock flats with two-spotted spider mites, _Tetranychus urticae_ (Koch), were cut and distributed over the new foliage. The dried leaves were removed after 2-3 days. A mature flat with _T.urticae_ could infest 4-8 new flats. Flats planted and infested every 2-3 days provide continuous spider mite production. Each day, the number of hours spent planting, infesting, spraying or sampling was recorded.

Flats with both M.occidentalis and T.urticae were more difficult to rear initially because the number of M.occidentalis available for initial inoculation of the flats were low, and predator-prey ratios became imbalanced, leading to substantial plant damage. Predator-prey flats were monitored once a week by sampling 4 leaflets/flat, which were brushed with a mite brushing machine, and counted under a dissecting microscope. If too few spider mites (less than 20 spider mites to 1 predator) were present, flats with T.urticae only could be cut and placed on the mixed flats. The spider mites moved off the cut plants to the recipient plants and dried foliage was removed within 1-2 days. If too many spider mites were present (more than 50 spider mites to I predator), a low rate of propargite (0.33 to 0.66 gram 30 WP O-mite/liter water) was applied using a handheld sprayer. At these rates the propargite is nontoxic to M.occidentalis and substantial suppression of the spider mites occurs. Ideal spider mite : predator ratios were between 20 and 40 spider mites : I predator so that unlimited growth of predator populations could occur.

If contaminating phytoseiids, such as Amblyseius californicus, were found in the weekly samples, carbaryl (3.0 gram 80 WP Sevin/liter water), permethrin (0.5 g A.I. 2 EC Ambush/100 liter water), diazinon (0.3 gram 25 EC/liter water) or sulfur (6.3 gram Ortho Flotox/liter water), were sprayed to drip on established flats or to new flats to control the contaminants and to keep the resistant strains pure. The different resistant strains were kept on separate greenhouse benches.

Leaf samples taken just before each harvest estimated the number of spider mites and M.occidentalis transferred to new flats or released into orchards or vineyards. The number of plants/flat and the number of leaflets/plant were estimated also.

Soybean Plot

The large scale predator rearing conducted in the soybean plot is dependent upon the availability of abundant spider mites and M.occidentalis for the initial inoculations, so it was necessary to rear both mite species in the greenhouse during April and May.

Experiment station personnel prepared the soil on 23 April 1981 at the University of California's West Side Field Station (WSFS) near Five Points, California and a preplant herbicide (alachlor 1.4 liter Lasso/2.4 hectare) was applied to the 0.2 hectare plot. Soybeans (cv. Williams) were planted on April 27 in 1 meter rows and 182 kg 16-20-0 fertilizer/ 2.47 hectares applied. The plants were furrow irrigated and cultivated.

By May 19, the soybeans had emerged and a total of 31 flats of greenhouse-reared pinto bean flats containing both M.occidentalis and T.urticae were released by cutting the plants and placing them on the soybean plants. Approximately 270,000 carbaryl-OP resistant female M.occidentalis were released. Carbaryl (1 lb/100 gallon) was applied to the plants with a highboy sprayer on July 15 to ensure the predator strain remained resistant and to remove any contaminating insect predators of the spider mites. The number of hours of labor by the WSFS personnel was estimated.

Predator-prey densities were estimated by sampling 10 leaflets/-row (total = 15 rows). The leaflets were placed in a refrigerated container, brushed with a mite brushing machine, and the mites were counted under a dissecting microscope.

3. Results

Greenhouse rearing

Table I lists the tasks and labor involved in producing bean plant flats containing T.urticae and M.occidentalis. Ten days after planting, the bean plants can be sprayed with sulfur, carbaryl, or permethrin depending upon the predator colony being reared. T.urticae are added at that time only if the flats to be used for infesting have a low prey:predator ratio, or less than 20 spider mites : 1 predator (all stages). Twelve days after planting, the resistant predator strain can be added to the flats by cutting mature bean plants from older flats and placing them on top of the foliage. Two days later the dried foliage should be removed. Leaflet samples are taken once a week until the flats to ensure appropriate predator:prey ratios are present and contaminating predators are absent.The total labor input for planting, watering, spraying, sampling, and counting is estimated to total 11.7 - 12.6 hours for 24 flats (or one bench) over the 42 day interval. Visual monitoring to determine irrigation needs, the presence of contaminating phytoseiid or insectan predators, and relative spider mite :predator densities should be done every day and requires at least 5 minutes/day/bench. Leaf samples taken just before harvest provide estimates of spider mite and predator numbers/leaflet; the counts of the number of plants/flat and number of leaflets/plant allow calculation of the number of M.occidentalis and T.urticae females availaboe for harvest or for infesting. The number of M.occidentalis and T.urticae released into orchards or vineyards can be varied by altering the number of plants released per tree/vine.

By these methods, a total of 227,000 permethrin-OP resistant M.occidentalis were released into the field from about 15.3 square meters of bench space during August and early September. Sulfur-OP resistant M.occidentalis were reared in 10.6 square meters of bench space and a total of 485,000 females were released during June, July and August. About 1,356,000 carbaryl-OP resistant predators were reared in 30.2 square feet of bench space; releases were made during June, July and August.

It is helpful if additional bench space (about 5.6 square meters) are available to produce extra spider mites. Several times during the rearing project, spider mite: predator ratios became too low and extra prey had to be added to the system.

Several difficulties arose during our greenhouse rearing (Table 2). If spider mite population levels became too high, they caused severe damage to the bean plants and the plants don't survive for the 3-4 weeks necessary to allow multiplication of the predators. The spider mites disperse from the dry, dead plants and substantial losses of predators then occur unless new flats are available for infestation by cutting the damaged plants. Daily and weekly sampling alerted us of this problem and timely applications of propargite were made. The second problem can be a shortage of prey for the predator. If the prey:predator ratio is less than 20:1, the predators will run out of food within a few days. If additional prey is not added, the predators will decline in numbers due to reduced oviposition, increased mortality, and perhaps dispersal from the plants. A third problem involved trying to hold the mature flats too long. Ideally, the flats will be harvested soon after the 4th week after infesting. If the plants need to be held longer, plants and predators are lost because plants are crowded and become shaded out. As a result, a flat with 75 plants in it may be reduced to 50 plants over a 2 week interval with a concomitant loss of predators. Contamination of the plants by other phytoseiid predator species was an occasional problem that could be solved by applying the appropriate pesticide since the contaminants were all susceptible to pesticides. Thus, if sulfur-OP resistant M.occidentalis were being reared, sulfur or diazinon would eliminate the invaders. Because the plants were kept so short a time, contamination by greenhouse whiteflies, thrips, or leafminers was minimal.

Soybean Plot

Labor at the 0.2 hectare soybean plot totaled ca. 82 hours; planting, fertilization and cultivation took 10.5 hours, furrow irrigation totaled 20 hours, cultivation and weeding took 10.5 hours and the carbaryl application took 1 hour. Spider mite and predator releases occurred periodically from May 26 to June 29 into the 15 rows and required a total of 14 hours labor.

The soybean plants grew quickly. Plants were 16.5 cm tall on June 3, 45.7 cm tall on June 29, 61 cm tall on July 8, and 99 cm tall on July 29. The number of leaflets/plant increased; 6,9,30,33 and 68 leaflets were present on May 26, June 12, June 29, July 29, and August 6, respectively. Despite abundant spider mite populations (Table 3), no defoliation occurred, in part because the plants were well watered. No acaricides were applied.

Sampling leaves over the season took 5 hours and counting the samples took 16 hours; other counts took a total of 5 hours. Leaflet samples showed an average of 8.3 females/leaflet on August 6 (Table 3). Since there were about 68 leaflets/plant on that date and 8.9

plants/0.3 meter in the 131 meter rows, we estimate there were 32 million carbaryl-OP resistant M.occidentalis females in the 0.2 hectare plot. In addition, there were about 30 million immatures and males and another 38 million M.occidentalis eggs on that date. Since about 180,000 females were released initially, this constitutes an 178-fold increase. The predator:prey ratios in Table 3 are approximate, but indicate that unlimited prey was available for the predators until the August 6 sample date. At that point we considered it likely that the predators would consume their prey within a few days, andharvest was scheduled to occur then so that predators would not be lost. At harvest, each plant contained an average of 300 M.occidentalis females. Releases were made using either portions of or entire plants, depending upon the inoculation levels required for each vine/tree.

The major advantage of the greenhouse rearing system is that it allows continuous production from April to October. It is a less efficient way to produce M.occidentalis than the field plot method. Another disadvantage is that contamination of strains can occur if they are reared in the same greenhouse unless appropriate sprays are applied regularly. Really large scale production was most efficient in the field plot. Its major disadvantage is the lateness of the production and its reliance upon the greenhouse rearing system for initial inoculation material. These two methods allowed inexpensive production of the carbaryl-OP, permethrin-OP and sulfur-OP resistant strains of M.occidentalis and should be adaptable for use with other pesticide-resistant phytoseiid species.

Table 1. Typical M. occidentalis - T. urticae production schedule in the University of California, Berkeley greenhouse during 1981[a/]

Date	Task/ growth stage	Labor (minutes) each task per 24 flats[b,c]
July 1	Plant flats, water, fertilize, add fungicide	35
July 5	Bean plants emerge	-
July 8	Dicotyledon leaf stage	-
July 10	Apply appropriate insecticide	20
	(optional: add spider mites if infesting material has few spider mites)	(20)
July 12	Infest flats with spider mites and M. occidentalis via cut bean plants	30
July 14	Remove dried bean plants; trifoliate stage	5
July 16	Sample 4 leaflets/flat, brush and count.	45
	Optional tasks, depending upon sample results	
	(a) spray propargite	(20)
	(b) spray insecticide	(45)
	(c) add spider mites	(30)
July 23	Ditto	45
		(20)
		(45)
		(30)
July 30	Ditto	45
		(20)
		(45)
		(30)
August 3	Ditto	45
		(20)
		(45)
		(30)
August 10	Preharvest leaflet sample;	45
	Preharvest plant and leaf sample;	30
	Optional, depending on sample results	
	(a) Spray propargite	(20)
	(b) Spray insecticide	(45)
	Harvest flat or use for infesting new flats	Total watering = 216 Total hand lens inspection = 145 Total other labor = 345 706 minutes Optional tasks = 1 3/4 hour (10-45 x 5) = (50 - 225 minute

Table 1. (cont'd)

a/ Temperature averaged 75°F, but ranged from 60° at night to a high of 90°F during the day.

b/ The flats were watered every day; about 5 minutes/24 flats was required in addition to the labor listed.

c/ Once the flats were infested with *T. urticae* and *M. occidentalis* they were examined for 5 minutes/day with a hand lens for contaminating phytoseiids, plant conditions, diseases, etc. in addition to the labor listed.

Table 2. Production schedule of the sulfur-OP-resistant *Metaseiulus occidentalis* strain in the University of California, Berkeley greenhouse - 1981.

No. flats on each bench	Date infested	Prey:predator ratio all stages at each sample date 1	2	3	4	Date flats harvested	Mean *M.o.* ♀♀/flat	Total no. *M.o.* ♀♀ kept for infesting	Total no. *M.o.* ♀♀ sent to field
4	stock	-	-	-	25	March 4	840	3,360	0
12	March 4	1/10	17	358	189	April 1	440	5,280	0
		S Tu	S	P					
39	April 1	316	790	297	32	May 18	4,160	128,960	0
		S P	P	P S					
13	May 18	-	24	23	12	June 10	4,740	23,700	37,920
		S	S D						
24	"	-	64	13	17	June 10	5,870	0	70,440
		S	S D			June 16	4,300	51,600	0
13	"	-	35	14	21	June 16	17,200	223,600	0
		S	S D						
17	June 10,16	3	20	0.6	-	July 2	2,900	20,300	29,000
		S,D,Tu	S,D						
24	"	98	13	1.5	-	June 30	5,200	0	83,200
		S,D	S,D			July 2		41,600	0
7	"	3	21	0.5	-	June 30	2,900	0	11,600
		Tu,S,D	S,D			July 2		0	8,700
24	July 2	31	4	25	12	July 14	3,800	22,800	0
		Tu,S	Tu			July 20		0	68,400
24	July 14	59	2	-	-	Aug. 4	3,800	30,400	0
		Tu,S,D				Aug.10	8,000	0	128,000
24	August 4	12	2	4	-	Aug.24	2,600	15,600	46,800
		S,Tu	S,Tu						

Table 2. (cont'd)

1/ Tu indicates addition of spider mites to system; P, D and S indicate propargite, diazinon or sulfur, respectively, were sprayed on the flats to reduce spider mites, remove contaminating phytoseiids such as *Amblyseius californicus*, or maintain the pure sulfur-OP resistant strain.

Table 3. Mean *T. urticae* : *M. occidentalis* densities/ soybean leaflet at the WSFS soybean plot - 1981. Ten leaflets/row were sampled, brushed and counted under a dissecting microscope.

Sample date	No. rows sampled	*T. urticae* eggs	*T. urticae* actives	*M. occidentalis* eggs	*M. occidentalis* imm.	*M. occidentalis* females	Ratio all stages Tu.: Mo.
19 June	6	21	11	0.3	0.2	0.2	46
29 June	8	33	10	0.2	0.3	0.3	54
8 July	4	151	29	0.8	0.6	0.6	90
21 July	15	30	14	0.5	0.7	1.0	20
29 July	14	514	58	6.3	1.8	2.4	54
6 August	15	356	83	9.9	7.7	8.3	17

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Large Scale Releases of a Genetically-Improved Biological Control Agent

Aerial Dispersal of *Metaseiulus occidentalis* documented for the first time.

Marjorie A. Hoy, William W. Barnett, Wilbur O. Reil, Darryl Castro, Daniel Cahn, Lonnie C. Hendricks, Richard Coviello and Walter J. Bentley

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Spider mites can be serious pests in California almond orchards. In some orchards, the mite Metaseiulus (=Typhlodromus) occidentalis (Nesbitt) is an effective predator of the Pacific and two-spotted spider mites, Tetranychus pacificus McGregor and T. urticae Koch, respectively. Pesticides used to control the navel orangeworm, Amyelois transitella (Walker), and the peach twig borer, Anarsia lineatella Zell., can disrupt this biological control, however. Carbaryl (Sevin) and the new pyrethroid permethrin (Ambush or Pounce) can cause serious spider mite outbreaks, by killing spider mite predators, including M.occidentalis, by stimulating spider mite reproduction, or by causing dispersal of spider mites, which also can enhance their reproduction.

M.occidentalis has been selected in the laboratory for resistance to carbaryl and to permethrin (California Agriculture, January 1980 and November-December 1980) as part of a genetic improvement project. The two strains, which are also resistant to organophosphorus insecticides, such as Guthion (azinphosmethyl), diazinon, and Imidan (phosmet), are called carbaryl-OP and permethrin-OP resistant. These strains have been evaluated in the laboratory, greenhouse, and small field plots to determine their ability to become established, control spider mites, overwinter in orchards, and survive commercial pesticide applications.

The concept of genetic improvement of biological control agents previously received little support because of concerns that laboratory-selected natural enemies might not be as effective as unselected "wild" strains. Because our previous field plots were small and not always managed "normally" by the grower, we conducted research on the

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feasibility of large-scale field releases of pesticide-resistant strains of predators for spider mite control. Goals were to rear resistant *M. occidentalis* and release them in San Joaquin Valley commercial almond orchards; document their establishment during the first season; document their ability to overwinter; and determine if pesticide rates can be reduced to manage spider mites and predators. This report describes our progress in rearing large numbers of the resistant predators, their establishment, and a previously unknown phenomenon--large-scale aerial dispersal of *M. occidentalis* from an almond orchard.

Predator rearing

Two systems were developed to produce predators. Most of the 1.5 million M. occidentalis females released in almond orchards during 1981 were reared on pinto beans, Phaseolus vulgaris (L), in a University of California, Berkeley, greenhouse. Plants were grown in flats containing one-half U.C. soil mix and one-half vermiculite. In the initial phase of greenhouse production (February to May) T. urticae were added to the bean plants as soon as dicotyledon leaves appeared. About one week later, resistant M.occidentalis were added. Plants were treated with carbaryl or permethrin periodically to ensure that the predator colonies remained resistant and that non-resistant predators were removed. Each strain was maintained on separate benches in the greenhouse.

Low rates of acaricide (Omite 30 WP,1/3 to 1/2 pounds /100 gallons water) were applied when predator-prey densities became imbalanced (usually more than 40 to 50 spider mites of all stages to 1 predator). After the predator-prey system stablized in May, predators were multiplied by cutting old plants containing both spider mites and M.occidentalis and placing them on clean young bean flats. These divisions yielded three new flats every two to three weeks during the summer.Continuous production of predators from June to September was possible, and about one million carbaryl-OP-resistant predator females and 227,000 permethrin-OP-resistant females were released.

Predators also were reared outdoors in a half-acre soybean plot in the San Joaquin Valley. This method required less labor than the greenhouse system, but large numbers of predators were not

available for release until early August. The soybeans were planted April 27, amd 31 flats of spider mites and carbaryl-OP-resistant predators were added on four occasions in June. Total input of M.occidentalis was estimated to be 180,000 females. By August, the plants were about 4 feet tall and could be harvested. Leaf samples taken on August 6 indicated that the half-acre plot contained approximately 32 MILLION M.occidentalis females, plus at least another 30 million immatures and males. Each soybean plant contained an average of 300 predator females.

This method was the least expensive in producing large quantities of predators in inoculative releases during August or September for large acreages. Control of spider mites can not be expected during the field season of release with these late releases. However, this procedure should be helpful in establishing a population that will be effective the following year.

Predator releases

In all cases, both predator strains were released in the orchard after the relevant insecticide had been applied so that native (susceptible) predators were largely eliminated. Pinto bean plants were cut and placed in the crotch of the tree. Release patterns and numbers released varied from orchard to orchard (see table), but most often 350 females were placed in every third tree, in every third row. Unknown numbers of males and immatures were released as well.

We expected establishment in the tree and spread from release trees to adjacent nonrelease trees sometime during the 1981 field season. Releases were made thoughout the summer when adequate prey were available to support the predators; that is, a minimal prey level of one-half to one spider mite of any stage per leaf. Black cotton cloth bands were stapled to major scaffolding limbs of release and nonrelease trees in all orchards during September. Overwintering female predators recovered from the bands during December and January will be tested in the laboratory to determine if they are resistant and well distributed in the release orchards.

Spider mite populations were managed by using low rates of Omite ($\frac{1}{2}$,1,or 2 pounds 30 WP per acre) or Plictran ($\frac{1}{2}$ or 1 pound per acre) both before and after predators were released. Use of these low rates sometimes gave poorer spider mite control than desirable if populations of M.occidentalis were not adequate or well distributed in the orchard. Weather, population densities, and irrigation schedules are also important in determining if these low rates give satisfactory control. If the weather is extremely hot, spider mite webbing has built up, or the orchard is water stressed, low rates of Omite or Plictran may not control spider mites sufficiently to prevent foliage damage.Thus, although low rates of these selective acaricides are potentially useful in spider mite management, considerable experience and monitoring are required to prevent excessive damage from spider mites. We will continue to evaluate such use of acaricides during 1982, because low rates can prevent predator-prey imbalances resulting from temporary loss of food, reduce grower costs, and retard development of resistance to these chemicals. Dominant resistance genes will be selected for more slowly in native spider mite populations if acaricides are used infrequently and at low rates. Plictran resistance has been found in spider mites in Oregon pear orchards recently (P.H. Westigard, personal communication), and serves as a warning of the potentially limited life span of these acaricides in California.

Aerial dispersal

We suspected that carbaryl-OP-resistant M.occidentalis dispersed aerially in the Bidart almond orchard near Bakersfield during 1979-80. A few predators had been released in August 1979 at one end of the block, and by August 1980 the carbaryl-OP-resistant predators were present thoughout the block in large numbers (Fig. 1), which indicated they had established, spread, and survived a carbaryl application in July 1980. An additional sample and laboratory test with carbaryl in April 1981 showed that the resistant strain had survived a second winter. Because the predators were so widely distributed over at least 50 acres, aerial dispersal was suspected.

In 1981, we conducted an experiment to determine if our suspicion was justified. Carbaryl-OP-resistant M.occidentalis were released on June 9 into every third tree, in every third row in an almond orchard (Livingston-1 in table). Carbaryl had been applied in May and again on July 3. Despite applications of 2 pounds 30 WP Omite per acre on July 3 and 21, spider mites increased and caused substantial foliage damage and some defoliation because populations were high when the acaricide was applied. The abundant spider mites also provided unlimited food for the predators, which multiplied extensively.

As foliage quality declined, spider mites (predominantly T.urticae and T.pacificus females) began to disperse from the orchard in July. Dispersal was detected by trapping the mites on sticky panels situated on two towers placed at the east end (downwind of prevailing winds) of the orchard on July 31. The 11-foot-high towers were about 25 feet from the edge of the orchard on a 2-foot levee. Six plastic panels 9 by 12 inches, were coated with high vacuum grease (Dow Corning) and attached at three levels on the tower. After removal from the orchard, the panels were scanned with a dissecting microscope, and spider mite and predator numbers were estimated by counting one-ninth of the panel area. Predators from the panels were slide-mounted and identified to species; all were M.occidentalis females. No immatures or males were recovered on the panels.

Aerial dispersal of M.occidentalis in the field has not been documented previously. The dispersal raises interesting questions about the fate of the resistant strains we have released. We know how to establish resistant predators in specific orchards after the relevant pesticide has been applied. However, we don't know how rapidly or how far these resistant predators will disperse from the release sites, or how to manage the resistance in the orchards or vineyards to which the resistant M.occidentalis disperse.

During 1980 and 1981, we inoculated 210 and 86 acres of almonds in the San Joaquin Valley with the carbaryl-OP- and permethrin-OP-resistant strains, respectively (fig. 2). It will be interesting to learn whether these orchards will serve as foci for the spread of carbaryl resistance (determined by a single major semidominant gene) into other orchards or vineyards. (Spread of the permethrin-OP resistant strain is not expected because the permethrin resistance is determined by several genes. If this strain interbreeds extensively with permethrin-susceptible wild predators, the resistance is lost.) Only careful monitoring of the area around these release sites can resolve our questions. It is clear for the first time, however, that M.occidentalis can disperse through the air. The relative importance of this method of dispersal remains to be resolved.

Table 1. Resistant M. occidentalis Releases in Almonds during 1981

Orchard location	Acreage	Strain released	Release date	Release pattern	No.♀♀ Released/ tree[1/]	Total ♀♀ released	No. bands[2/]
N. Palm & North Ave. Turlock - I	3	Carbaryl-OP	July 31	2nd tree 3rd row	500	50,000	40
N. Palm & North Ave. Turlock - II	6	Permethrin-OP	July 31	3rd tree 3rd row	1000	34,300	80
Washington & Westside Rd. Livingston - I	14	Carbaryl-OP	June 9	3rd tree 3rd row	350	61,600	100
Washington & Westside Rd. Livingston - II	10	Carbaryl-OP	Aug. 15	3rd tree 3rd row	350	60,000	40
Ave. 18 & Rd. 20 Madera	6	Carbaryl-OP	July 21	every tree	300	180,000	74
Hwy 33 & Mountain View Three Rocks	80	Carbaryl-OP	July 10	3rd tree 3rd row	350	555,400	240
Merced & Palm Ave. Wasco	20	Permethrin-OP	Sept. 15	3rd tree edges only	200	8,600	30
Hwy. 46 & Palm Ave. Wasco	15	Carbaryl-OP	May 28	5th tree 5th row	2900	175,000	40
Hwy. 46 & 43, Block 32-4 Blackwell Corners	60	Permethrin-OP	Aug. 5	3rd tree 3rd row	350	165,000	100

1/ Based on prerelease counts of bean plants.
2/ Trees were banded on Sept. 15, 16, or 17 to monitor overwintering success and resistance levels of M. occidentalis.

Fig. 1. Greenhouse mass rearing of M.occidentalis using pinto beans infested with two spotted spider mites. One predator-infested flat can be cut and distributed on 4 new flats for multiplication of predators. Over 1 $\frac{1}{2}$ million resistant predators were produced during June-August by this method.

Fig. 2. Mass rearing of resistant M.occidentalis in a $\frac{1}{2}$ acre soybean plot in the San Joaquin Valley. Soybean plants contained about 300 predator females each in late July. Cut plants are placed into the crotch of almond trees and predators move into the tree from the wilting bean plants. Approximately 32 million predator females were present in this $\frac{1}{2}$ acre plot on August 6.

Fig. 3. Diagram of the Bidart almond orchard where carbaryl-OP resistant *M.occidentalis* were released in August 1979. Predators recovered in 1980 and 1981 were resistant to carbaryl, indicating extensive movements had occurred in this 80 acre orchard.

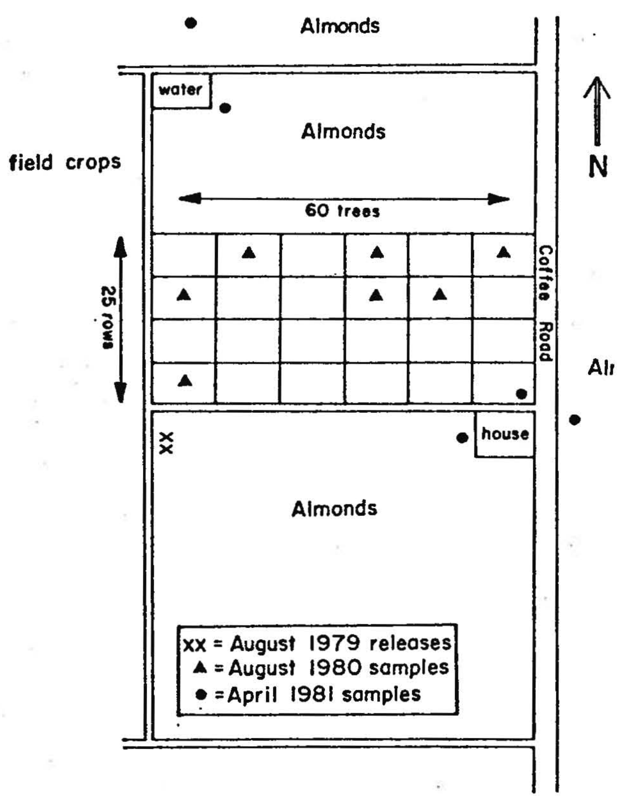
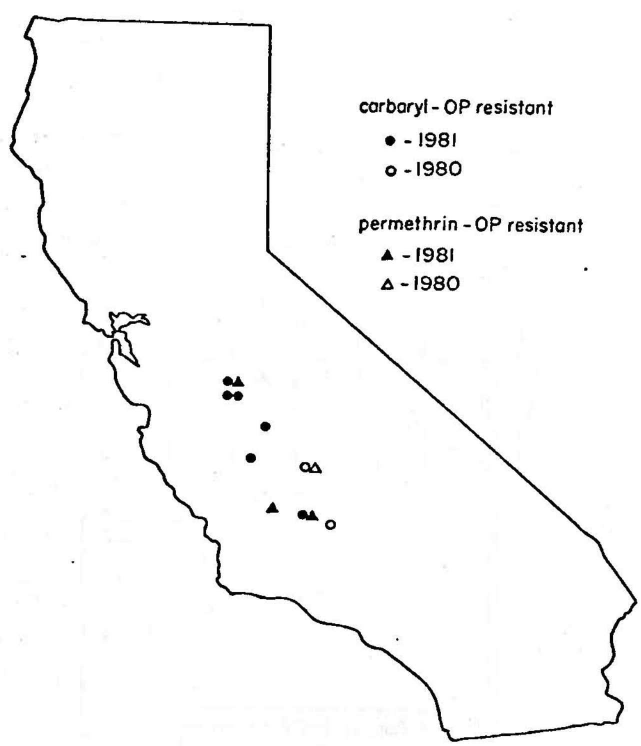


Fig. 4. Dispersal of carbaryl-OP and permethrin-OP resistant <u>M.occidentalis</u> from almond orchards where releases were made in 1980 and 1981.



RAVETTO - TURLOCK

Grower/Advisor: Dale Ravetto
CORTEZ GROWERS
Address: ______
Phone: (209) 632-7339
(209) 632-3118

UC Ext. Personnel: BILL BARNETT
Address: ______
Phone: ______

Location: N. PALM AVE x NORTH AVE
Acreage: 15

Block Size/ 81 Rows x 17 Trees
Tree Spacing: ______

Varieties: ______
Varietal Pattern: ______

Irrigation: SPRINKLER

Pre-Release Colony: Y N

Pesticide Notes:

Date	Material	Concentration	Notes

1981 Release Data:
CARBARYL
PERMETHRIN

Date: 7-31-81
Pattern Type: EVERY OTHER T / EVERY 3rd R

No. ♀♀ Released/ Release Tree: C 500/T P 1000

Total Released: C 50,000 P 34,300 ♀♀

Sample Data:

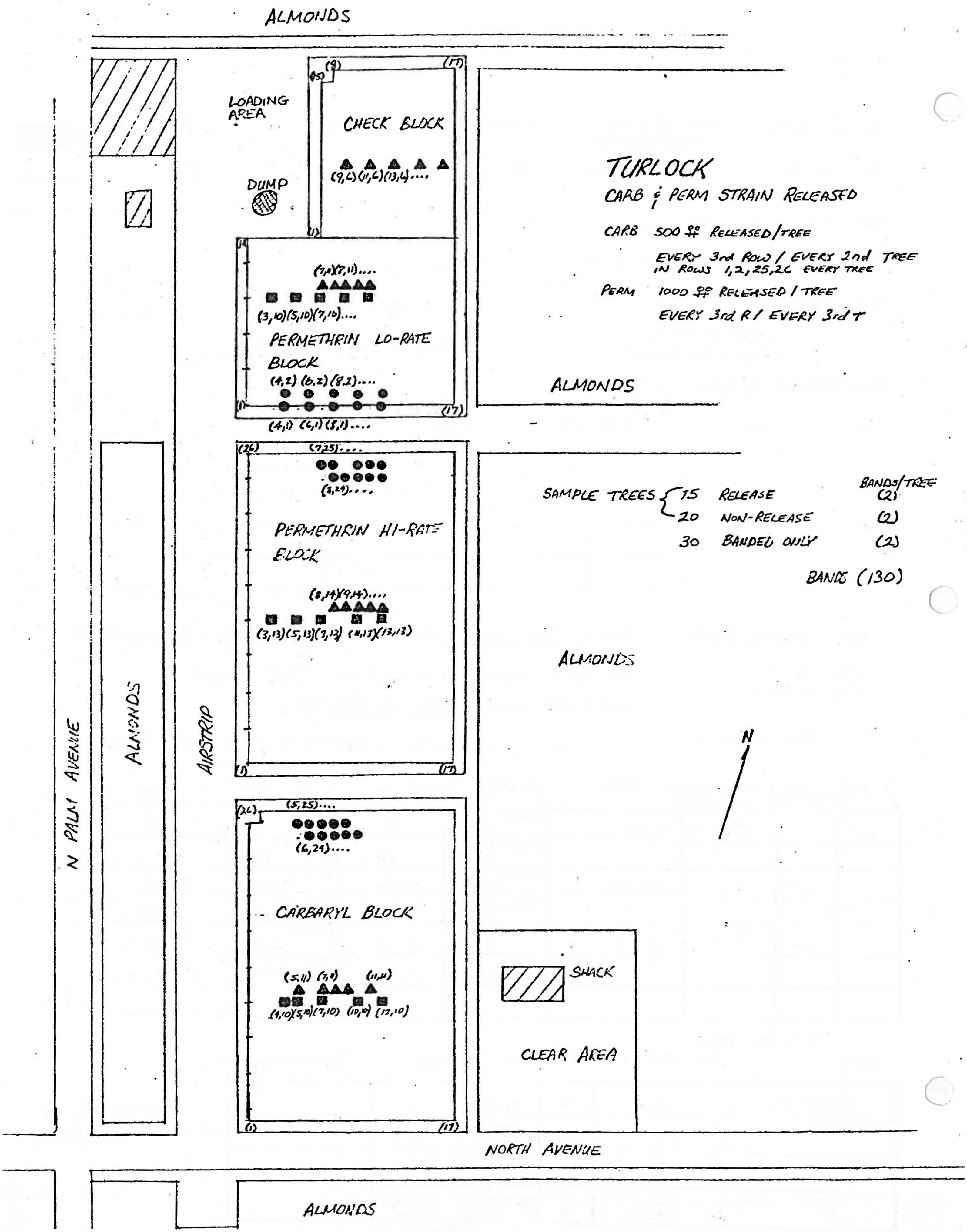
Mean/ Leaf Values (Leaves brushed and counted on per tree basis)

Pre Release	Post Release	No. trees sampled	Date	Release Trees SM	Release Trees MO	Check Trees SM	Check Trees MO
✓		20	7-31	CARB 0.84	0	CHECK 0	0
				PERM LO 0.42	0	PERM HI 0.60	0
	✓	20	8-20	CARB 2.26	0.02	CHECK 2.20	0.12
				PERM LO 0.27	0.0	PERM HI 2.96	0.10
	✓	20	9-15	CARB 2.12	0.84	CHECK 0.30	0.22
				P-LO 0.26	0.02	P-HI 3.96	1.18

Banding Data:

Date	No Trees	Bands/tree	Type	Recovery Dates
8-15-81	5	2	CHECK	
	15	2	RELEASE 5/spray block	
	15	2	NON-RELEASE 5/spray block	
	30	2	BANDED ONLY 10 each spray	

Total No. of bands: 130


ALMONDS
LOADING AREA
DUMP
CHECK BLOCK
(9,6) (11,6) (13,6)....
TURLOCK
CARB & PERM STRAIN RELEASED
CARB 500 ♀♀ RELEASED / TREE
EVERY 3rd ROW / EVERY 2nd TREE
IN ROWS 1,2,25,26 EVERY TREE
PERM 1000 ♀♀ RELEASED / TREE
EVERY 3rd R / EVERY 3rd T
(7,11)(9,11)....
(3,10)(5,10)(7,10)....
PERMETHRIN LO-RATE BLOCK
(4,2) (6,2) (8,2)....
(4,1) (6,1) (8,1)....
ALMONDS
(7,25)....
(8,24)....
PERMETHRIN HI-RATE BLOCK
(8,14)(9,14)....
(3,13)(5,13)(7,13) (11,13)(13,13)
SAMPLE TREES
15 RELEASE
20 NON-RELEASE
30 BANDED ONLY
BANDS/TREE
(2)
(2)
(2)
BANDS (130)
ALMONDS
N
N PALM AVENUE
ALMONDS
AIRSTRIP
(5,25)....
(6,24)....
CARBARYL BLOCK
(5,11) (7,11) (11,11)
(3,10)(5,10)(7,10) (10,10) (12,10)
SHACK
CLEAR AREA
NORTH AVENUE
ALMONDS

Livingston I

Grower/Advisor: C.V. Horton Address: ____ Phone: ____

UC Ext. Personnel: Lonnie Hendricks Address: Merced Co. FA Phone: 209-726-7404

Location: Westside + Washington Acreage: 14

Block Size/ 38 Rows x 43 Trees (Block I) Tree Spacing: 15×25

Varieties: Mono, Yosemite, Mission Varietal Pattern: ____

Irrigation: flood

Pre-Release Colony: Y (N)

Pesticide Notes:

Date	Material	Concentration	Notes

1981 Release Data: Date: June 9, 1981 Pattern Type: 3 row - 3rd tree

No. ♀♀ Released/ Release Tree: 350 ♀♀

Total Released: 61,600 ♀♀

Sample Data: Mean/ Leaf Values (Leaves brushed and counted on per tree basis)

Pre Release	Post Release	No. trees sampled	Date	Release Trees SM	Release Trees MO	Check Trees SM	Check Trees MO
/		20	6-9-81	.67	.02	.15	.01
	/		7-8-81	4.49	.10	3.85	.03
	/		7-17-81	4.33	.61	6.59	.26
	/		7-27-81	9.96	2.39	6.33	.62
	/		7-31-81	7.99	1.51	5.58	.14
	/		8-6-81	4.95	3.27	5.30	1.18
	/		8-20-81	.03	.59	.046	.43
			8-28-81	.01	.47	.03	.34
			9-17-81	0	0	0	0

Banding Data:

Date	No Trees	Bands/tree	Type	Recovery Dates
9-15-81	28	2		

Total No. of bands: 56

Grower/Advisor: CV Horton Address: ______ Phone: ______

UC Ext. Personnel: Lonnie Hendricks Address: Merced Co FA Phone: 209-726 74[illegible]

Location: Westside + Washington Acreage: 7

Block Size/ 33 Rows x 25 Trees Tree Spacing: 25 x 15

Varieties: ______ Varietal Pattern: ______

Irrigation: FLOOD

Pre-Release Colony: Y N

Pesticide Notes:

Date	Material	Concentration	Notes

1981 Release Data: Date: Sept 15, 1981 Pattern Type: 3rd row 3rd tree

No. ♀♀ Released/ Release Tree: 350

Total Released: 60,000 ♀♀

Sample Data: Mean/ Leaf Values (Leaves brushed and counted on per tree basis)

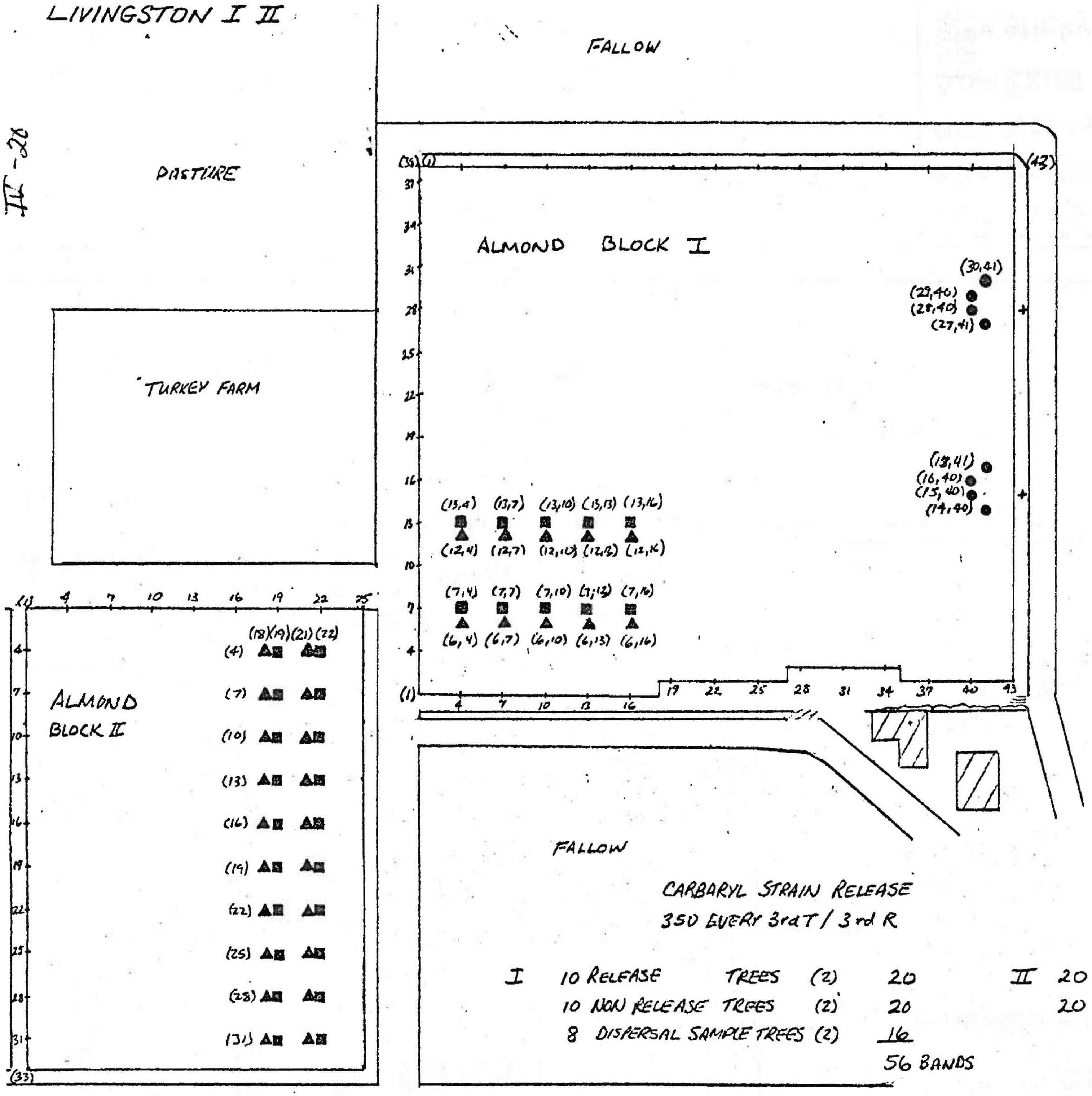
Pre Release	Post Release	No. trees sampled	Date	Release Trees SM	Release Trees MO	Check Trees SM	Check Trees MO
			NONE [illegible]				

Banding Data:

Date	No Trees	Bands/tree	Type	Recovery Dates

Total No. of bands: ______

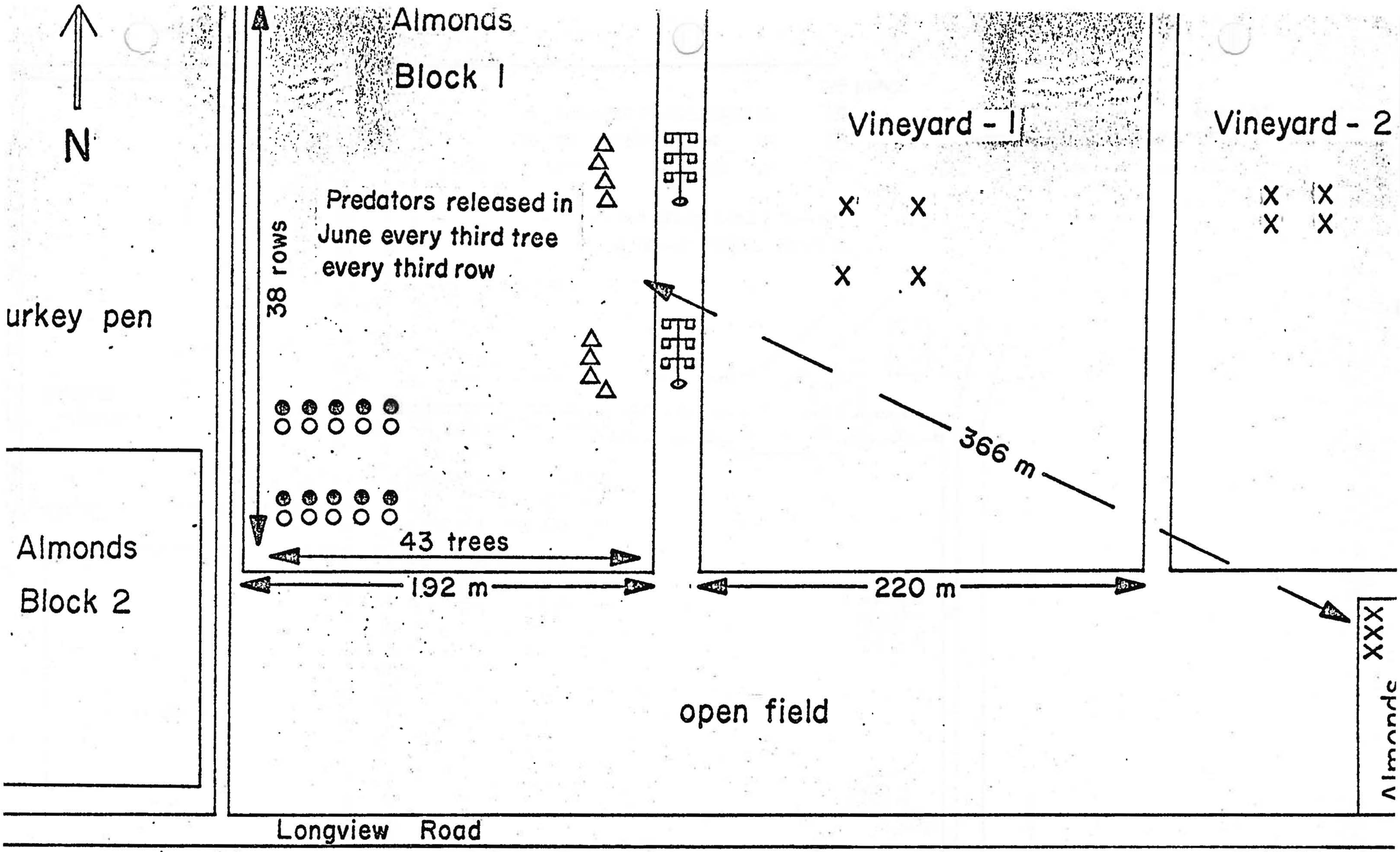
LIVINGSTON I II



CARBARYL STRAIN RELEASE
350 EVERY 3rd T / 3rd R

I	10 RELEASE TREES	(2)	20
	10 NON RELEASE TREES	(2)	20
	8 DISPERSAL SAMPLE TREES	(2)	16
			56 BANDS

II	20 RELEASE	(1)	20
	20 NON RELEASE	(1)	20
			40 BANDS



Livingston I & II

Three Rocks

Grower/Advisor: Pecks Ranch (TODD Browne PCA) Address: ________ Phone: ________

UC Ext. Personnel: B Barnett Address: Fresno FA Phone: ________

Location: Hwy 33 + Mountain View Acreage: 80

Block Size/ 60 Rows x 109 Trees

Tree Spacing: 22x24 diagonal 82 tree/

Varieties: Nonpareil, Carmel

Varietal Pattern: ________

Irrigation: drip

Pre-Release Colony: (Y) N

Pesticide Notes:

Date	Material	Concentration	Notes

1981 Release Data:

Date: 7-10-81 / 7-29-81 Pattern Type: 3rd row - 3rd tree

No. ♀♀ Released/ Release Tree: 350 ♀/

Total Released: 555,400 ♀♀

Sample Data:

Mean/ Leaf Values (Leaves brushed and counted on per tree basis)

Pre Release	Post Release	No. trees sampled	Date	Release Trees SM	Release Trees MO	Check Trees SM	Check Trees MO
/	~~/~~		6-29-81	.13	.02	.37	.03
/			7-10-81	.03	0	.43	.13
	/		7-21-81	1.03	0	.66	.01
	/		7-29-81	1.41	.01	3.01	0
	/		9-16-81	.12	.08	.18	.06
	/						

Banding Data:

Date	No Trees	Bands/tree	Type	Recovery Dates

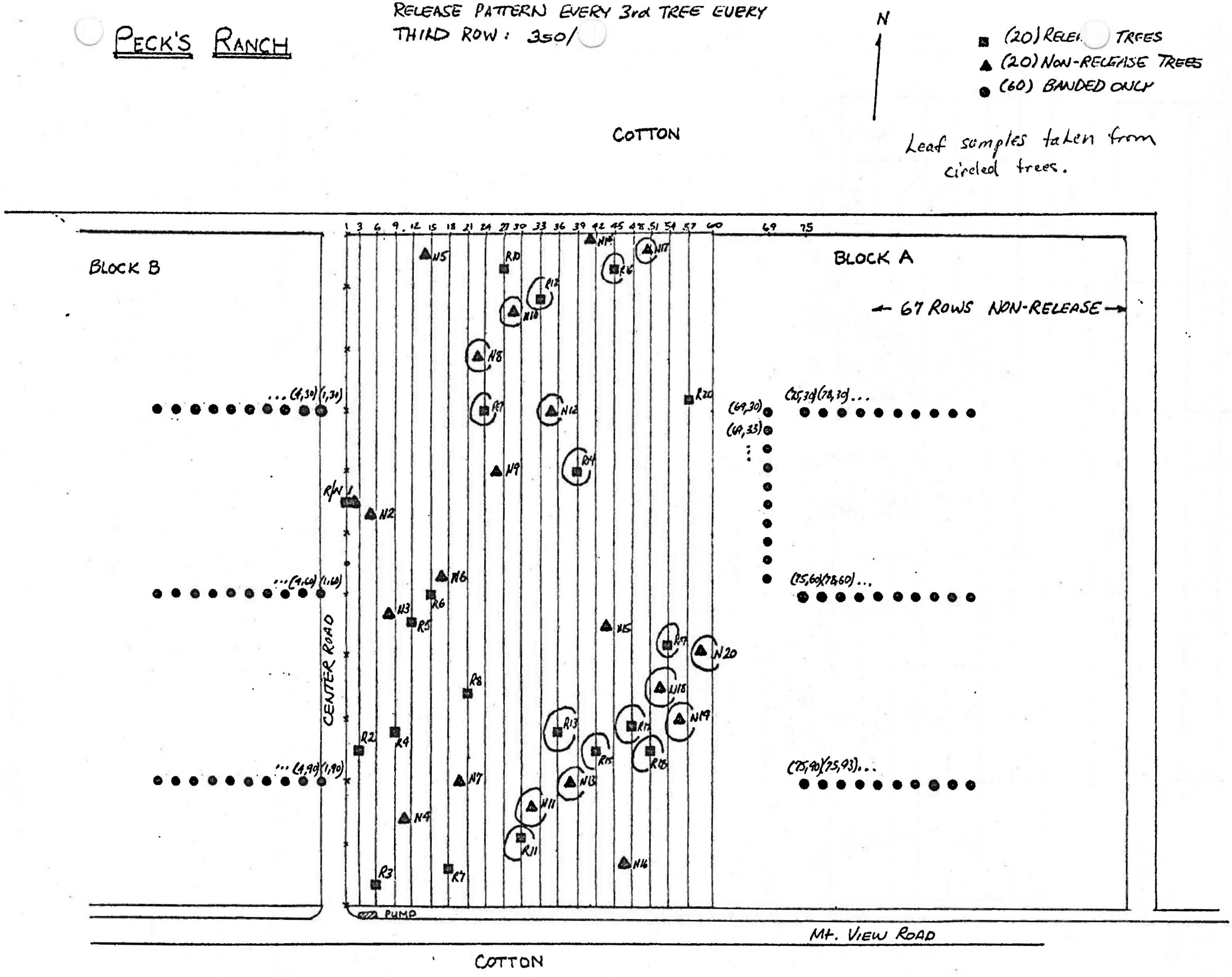
Total No. of bands: ________

PECK'S RANCH

RELEASE PATTERN EVERY 3rd TREE EVERY THIRD ROW : 350/

- ■ (20) RELEA… TREES
- ▲ (20) NON-RELEASE TREES
- ● (60) BANDED ONLY

Leaf samples taken from circled trees.



BLACKWELL'S LAND CO BLOCK 32-4

Grower/Advisor: EARL SURBER Address: STAR RT. BOX 337, LOST HILLS 93249 Phone: (805) 465-5611 465-5663

UC Ext. Personnel: WALT BENTLEY Address: 2610 M ST BOX 2509 BAKERSFIELD 93303 Phone: (805) 861-2631

Location: HWY 46 + HWY 33 Acreage: 80

Block Size/ 109 Rows x 49 Trees Tree Spacing: ____

Varieties: ____ Varietal Pattern: ____

Irrigation: SPRINKLER

Pre-Release Colony: Y N

Pesticide Notes:

Date	Material	Concentration	Notes

1981 Release Data: Date: 8-5-81 Pattern Type: 3rd T/3rd R

No. ♀♀ Released/ Release Tree: 350

Total Released: ≈ 16500♀♀

Sample Data:

Mean/ Leaf Values (Leaves brushed and counted on per tree basis)

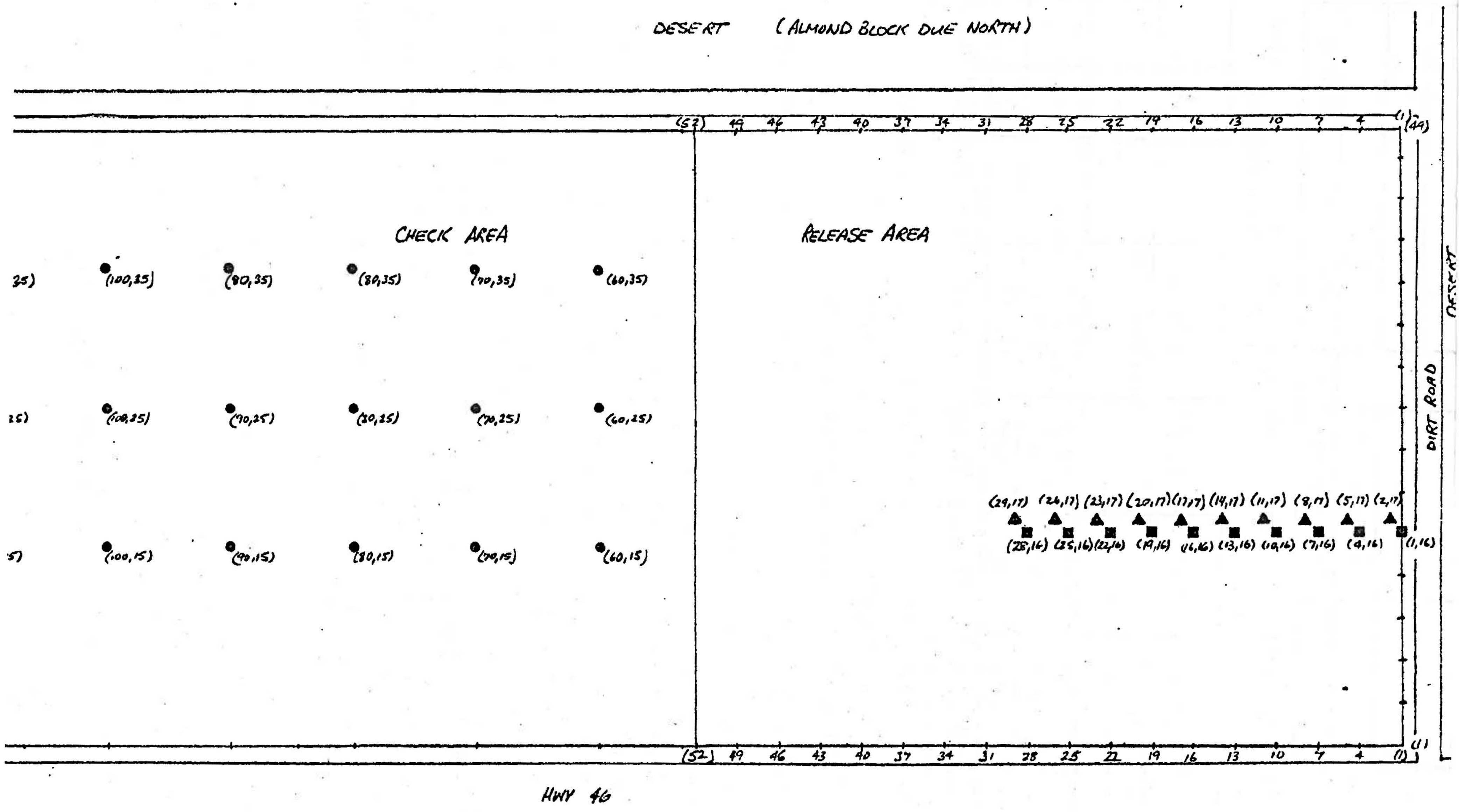
Pre Release	Post Release	No. trees sampled	Date	Release Trees SM	Release Trees MO	Check Trees SM	Check Trees MO
✓			6-2-81	0.03	0	0.06	0
✓			7-2-81	0.44	0.02	0.72	0.02
✓			8-5-81	4.60	0.02	4.20	0
			90% DEFOLIATION				
	✓		9-16-81	0.22	0	0.29	0

Banding Data:

Date	No Trees	Bands/tree	Type	Recovery Dates
9-16-81	10	2	RELEASE SAMPLE	
	10	2	NON RELEASE	
	18	2	CHECK AREA	

Total No. of bands: 74

BLACKWELL'S LAND CO. BLOCK 32-4



PERMETHRIN STRAIN RELEASE
350 ♀♀/ TREE
EVERY 3rd T/3rd R

DESERT

SAMPLED { 10 RELEASE (2) ■
10 NON-RELEASE (2) ▲
18 CHECK BLOCK (2) ●
76 BANDS

MERCED & PALM AVE. - WASCO

Grower/Advisor: ________ Address: ________ Phone: ________

UC Ext. Personnel: WALT BENTLEY Address: 2610 M. St BAKERSFIELD P.O. BOX 2509 93303 Phone: (805) 861-21

Location: MERCED + PALM/WASCO Acreage: 20

Block Size/ Rows x Trees Tree Spacing: ________

Varieties: ________ Varietal Pattern: ________

Irrigation: ________

Pre-Release Colony: Y N

Pesticide Notes:

Date	Material	Concentration	Notes

1981 Release Data: Date: 9-15-81 Pattern Type: 3rd Tree EDGES ONLY

No. ♀♀ Released/ Release Tree: 200

Total Released: 8600 ♀♀

Sample Data:

Mean/ Leaf Values (Leaves brushed and counted on per tree basis)

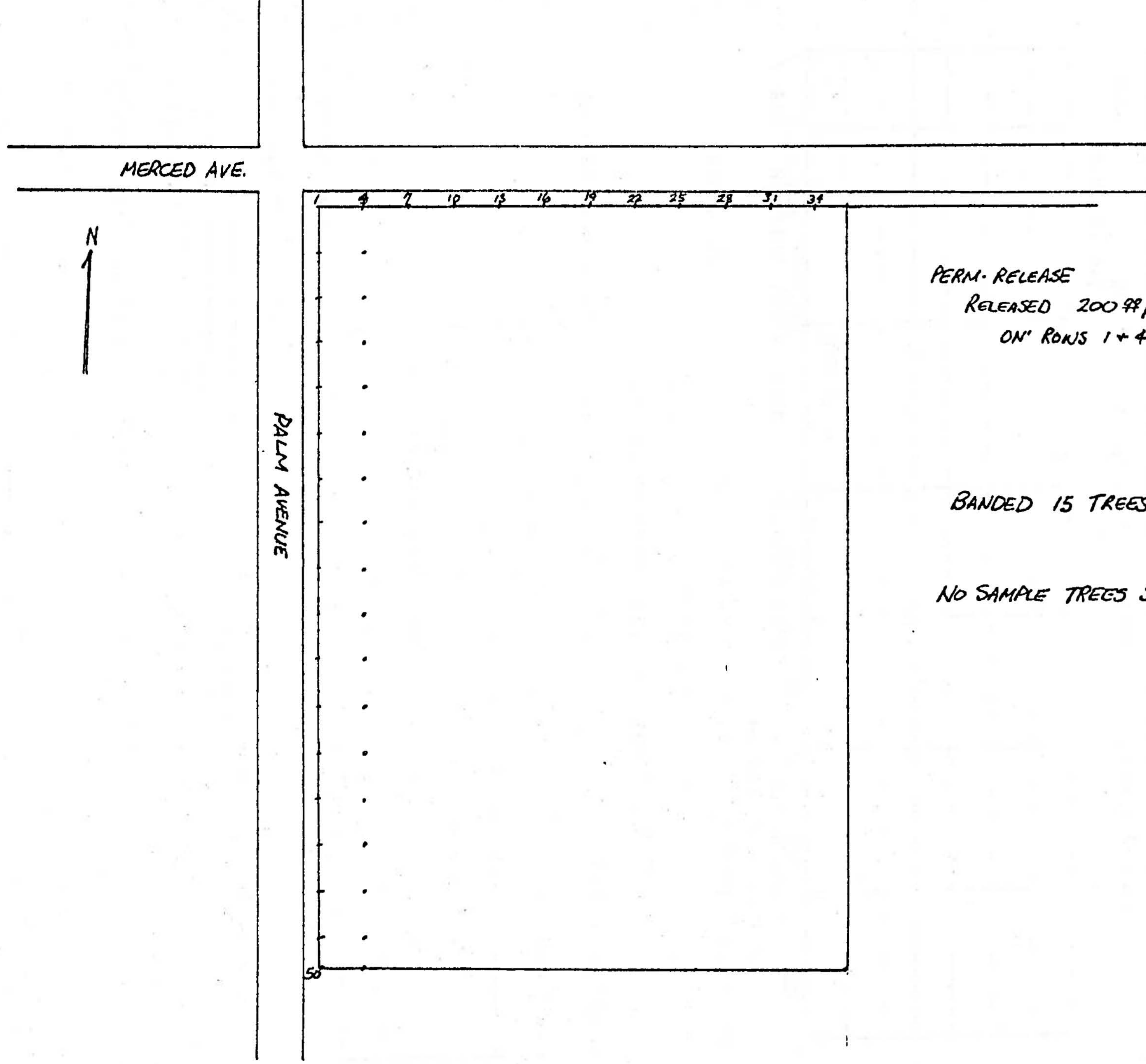
Pre Release	Post Release	No. trees sampled	Date	Release Trees SM	Release Trees MO	Check Trees SM	Check Trees MO
			NONE —				

Banding Data:

Date	No Trees	Bands/tree	Type	Recovery Dates
9-15-81	15	2	YELLOW PAINT EDGES - INTERIOR	

Total No. of bands: 30

WASCO - PERMETHRIN RELEASE



PERM. RELEASE
RELEASED 200 ♀♀/TREE
ON ROWS 1 + 4 and NORTH EDGE

BANDED 15 TREES (2)

NO SAMPLE TREES SET UP

40 x Palm / Wasco
Kern Co.

Grower/Advisor: ______ Address: ______ Phone: ______

UC Ext. Personnel: Walt Bentley Address: 2610 M St. Bakersfield PO Box 2509 93303 Phone: (805) 861-2631

Location: Hwy 46 x Palm Ave. /Wasco Acreage: 15

Block Size/ 23 Rows x 60 Trees Tree Spacing: ______

Varieties: ______ Varietal Pattern: ______

Irrigation: Flood

Pre-Release Colony: (Y) N

Pesticide Notes:

Date	Material	Concentration	Notes
6/3	Omite	[illegible]	ERM - SCRUBBED PLOT

[illegible] (handwritten beside table)

1981 Release Data: Date: 5/28/81 Pattern Type: Every 5 trees/5 rows

No. ♀♀ Released/ Release Tree: 2880

Total Released: 200,000 ♀♀

Sample Data: Mean/ Leaf Values (Leaves brushed and counted on per tree basis)

Pre Release	Post Release	No. trees sampled	Date	Release Trees SM	Release Trees MO	Check Trees SM	Check Trees MO
✓		20	5/28/81	0.55	0.020	0.54	0.030
	✓	6	7/20/81	0.21	0	-	-

Banding Data:

Date	No Trees	Bands/tree	Type	Recovery Dates
8-11-81	10	1	Release	
	20	1	Banded only	
	10	1	Non-Release	

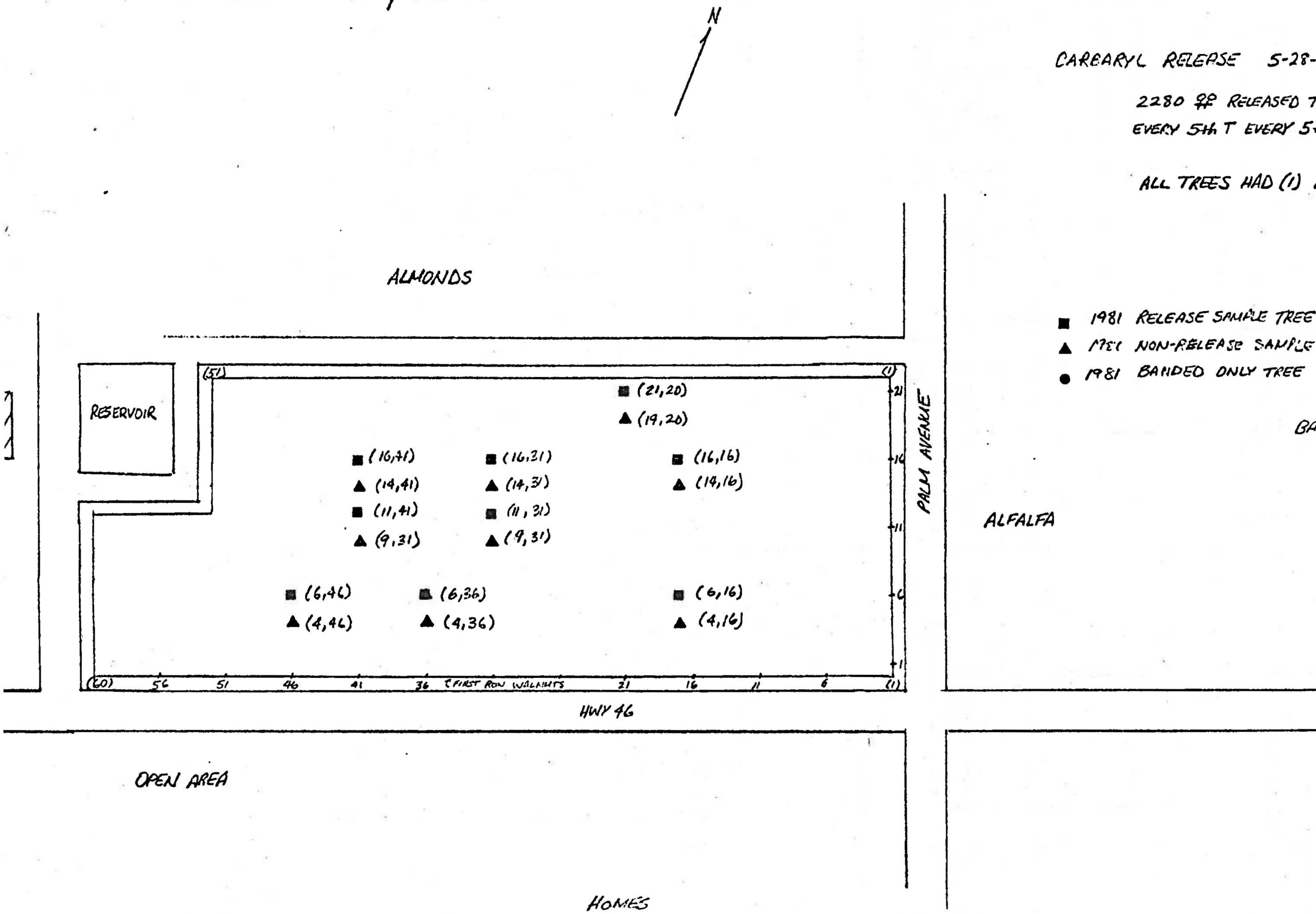
Total No. of bands: 40

WASCO – 46 & PALM

CARBARYL RELEASE 5-28-81

2280 ♀♀ RELEASED TREE
EVERY 5th T EVERY 5th R

ALL TREES HAD (1) BAND



■ 1981 RELEASE SAMPLE TREE (10)
▲ 1981 NON-RELEASE SAMPLE TREE (10)
● 1981 BANDED ONLY TREE (20)

BANDS 40

BIDART'S - BAKERSFIELD

Grower/Advisor: RANDY GRIGG Address: ______ Phone: ______

UC Ext. Personnel: ______ Address: ______ Phone: ______

Location: ______ Acreage: ______

Block Size/ Rows x Trees Tree Spacing: ______

Varieties: ______ Varietal Pattern: ______

Irrigation: FLOOD

Pre-Release Colony: Y N

Pesticide Notes:

Date	Material	Concentration	Notes
Jan 19	SUPREME OIL PARATHION	4gal/A 3pt/A	
May 4	GUTHION	4lbs/A	NOW
June 27	GUTHION+Oil	4lbs/A 4pts/A	BORDER TREATMENT 2 passes NOW+
July 3	IMIDAN	8lbs/AC	NOW HULLSPLIT
July 20	OMITE	4pts/AC (L-E)	Mites

1981 Release Data: Date: ______ Pattern Type: ______

No. ♀♀ Released/ Release Tree: ______

Total Released: ______ ♀♀

Sample Data:

NONE TAKEN

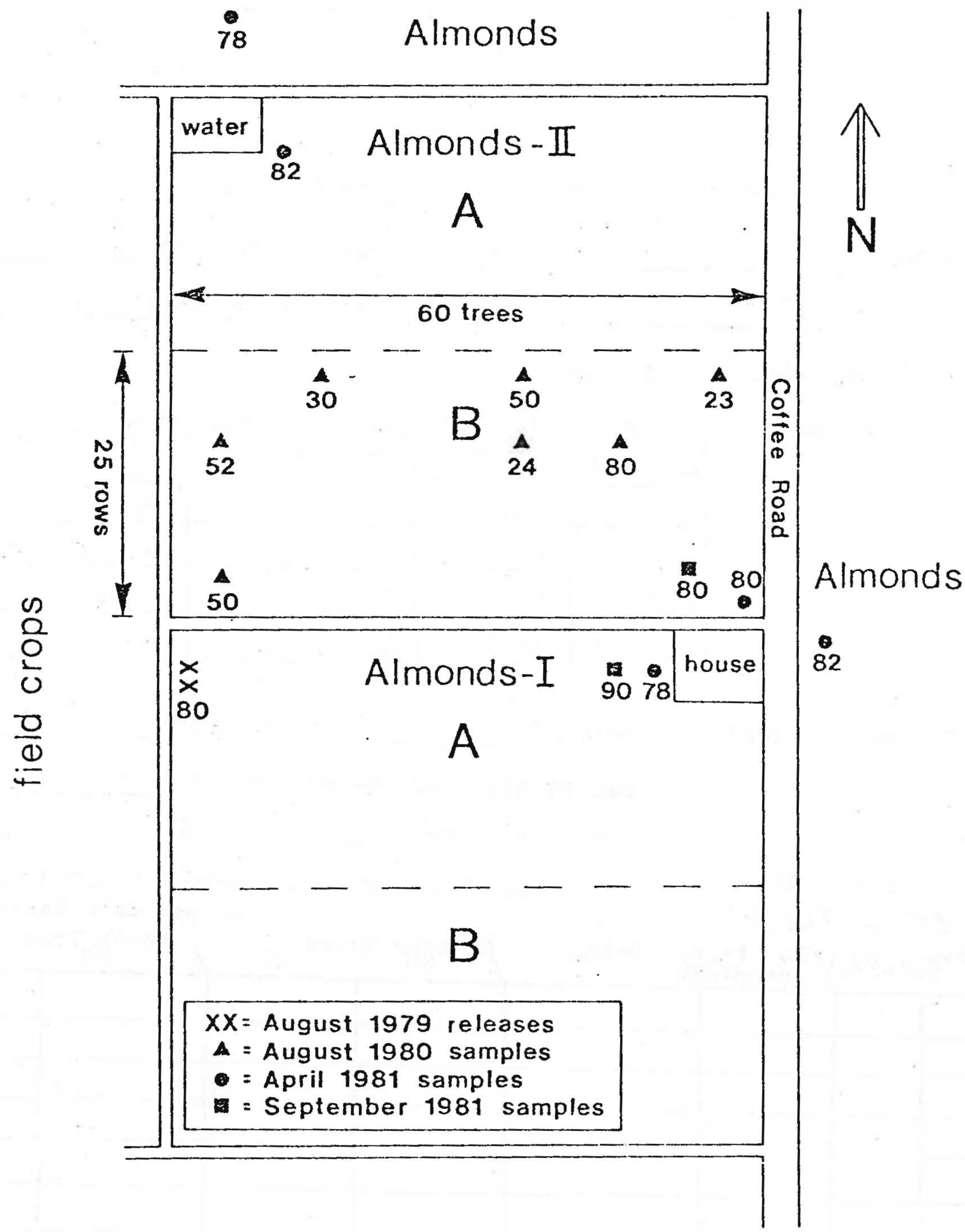
Mean/ Leaf Values (Leaves brushed and counted on per tree basis)

Pre Release	Post Release	No. trees sampled	Date	Release Trees SM	Release Trees MO	Check Trees SM	Check Trees MO

Banding Data:

Date	No Trees	Bands/tree	Type	Recovery Dates
9-15-81	10	1	EDGE "DUSTY ROAD"	
	20	1	RANDOM IN BLOCK	

Total No. of bands: 30



78
Almonds
water
82
Almonds - II
A
N
60 trees
30
50
23
B
52
24
80
25 rows
Coffee Road
50
80
80
Almonds
field crops
XX
80
Almonds-I
90
78
house
82
A
B
XX= August 1979 releases
▲ = August 1980 samples
● = April 1981 samples
■ = September 1981 samples

AERIAL DISPERSAL AND EFFICACY OF A GENETICALLY-IMPROVED STRAIN OF THE SPIDER MITE PREDATOR *METASEIULUS OCCIDENTALIS* (ACARINA, PHYTOSEIIDAE)

MARJORIE A. HOY

201 Wellman Hall, Department of Entomological Sciences,

University of California, Berkeley, CA 94720 U.S.A.

ABSTRACT

Carbaryl-resistant Metaseiulus (=Typhlodromus or Galendromus) occidentalis (Nesbitt) released in August 1979 into a few trees at the edge of an 32 hectare almond orchard near Bakersfield, California. In August 1980, predators were collected from 7 sites wisely separated in the orchard had moderate to high levels of carbaryl resistance. Because it is unlikely M.occidentalis could have dispersed so far by walking, aerial dispersal was suspected. Predators sampled in April and September 1981 also were carbaryl resistant, indicating that this strain had survived a second winter and field season. During June 1981 the carbaryl-resistant strain was released into an almond orchard near Livingston, California. Large numbers of M.occcidentalis were collected in August on sticky panels located outside the orchard downwind from the prevailing winds. Thus, aerial dispersal by M.occidentalis was detected in the field for the first time. Thus, this laboratory-selected strain may be capable of substantial dispersal on its own.

Metaseiulus (=Typhlodromus or Galendromus) occidentalis (Nesbitt) is an important predator of spider mites in western North American deciduous orchards and vineyards. An organophosphorus insecticide (OP)-resistant strain has been released and established in Australian and New Zealand deciduous orchards. M.occidentalis acquired resistance to OP insecticides and to sulfur through natural selection in orchards and vineyards (Hoy et al. 1979, Hoy and Knop 1979, Hoy and Standow 1981). Carbaryl and permethrin resistance was developed through artificial selection in the laboratory as part of a genetic improvement program with this predator (Roush and Hoy 1981a, Hoy and Knop 1981).

Field efficacy tests involving these 2 resistant strains have been conducted in small plots involving a few trees (Hoy et al.1980, Roush and Hoy 1981b). The assumption was made that these resistant predators would stay within individual release trees for substantial periods of time (weeks or months), and that adjacent trees could receive a different predator strain without fear of rapid mixture or interbreeding (Croft 1976). Croft and Barnes (1972) found that an OP-resistant strain of M.occidentalis did not move substantial distances in their trials in a southern California apple orchard over a 2 year period, and Hoy and Westigard (In prep.) found the permethrin-resistant strain of M.occidentalis moved into adjacent trees only during the second year in Oregon pear orchards. Field (1978) in contrast, found that the OP-resistant strain of M.occidentalis spread throughout the Australian peach orchard within one year.

During August 1980, carbaryl-resistant M.occidentalis were found throughout a 32 hectare almond block after having been released in August 1979 into a few trees only at one end of the orchard. As it seemed unlikely that the predators could disperse by walking, aerial dispersal of this laboratory-selected resistant strain was suspected.

Dispersal mechanisms in phytoseiid mites are not well understood. Johnson and Croft (1976) described a specific behavior believed to be involved in the aerial dispersal of Amblyseius fallacis (Garman). Adult preovipositing females, ovipositing females, and to a lesser extent adult males, altered their behavior from a random search movement to a directed movement toward the edge of an arena. They terminated forward motion, oriented to an air flow of ca. 1600 meter/hour and raised their anterior body away from the substrate. Air currents effected dispersal, and starvation and temperature influenced this behavior (Johnson and Croft, 1976). Field (1981) described similar behavior in the carbaryl-resistant strain of M.occidentalis under laboratory conditions.

This paper documents the extensive dispersal of the carbaryl-resistant strain in a Bakersfield almond orchard during 1979-1980 and its survival for 2 full years there. In addition, evidence is presented that M.occidentalis can disperse aerially in a Livingston, California almond orchard.

Materials and Methods

Dispersal in the Bakersfield almond orchard

A total of 2-3000 carbaryl-resistant M.occidentalis were released into 3-4 trees along the edge of an almond orchard near Bakersfield, California in late August 1979 by R.T. Roush after Blocks I-A and II-A had been treated with carbaryl (1.8 kg 80S Sevin / hectare) in July 1979 (Fig. 1). Carbaryl nearly eliminated the native susceptible M.occidentalis. Carbaryl was not applied in blocks I-B or II-B during 1979 (Fig. 1). In 1980, block II-B was used to evaluate the use of low rates of propargite to control spider mites. Carbaryl was applied on July 15, 1980 in blocks I and II, and propargite was applied on July 29 (0,120,240, and 600 gram 30 WP Omite/100 liters water) to block II-B. Spider mites (predominately Tetranychus urticae (Koch) and T.pacificus (McGregor)) and M.occidentalis were monitored by sampling 20 leaves/tree from 24 trees of each treatment (total= 96 trees) in block II-B. The leaves were kept chilled until they could be brushed with a mite brushing machine and counted under a dissecting microscope. M.occidentalis were recovered from the orchard, colonized, and 30-80 gravid females were tested with 2.4 gram AI carbaryl (80 WP Sevin)/liter water sprayed on 2 cm diameter pinto bean leaf discs (Phaseolus vulgaris (L)) containing T.urticae as prey. Survival was assessed after 48 hours. Samples were taken from 7 sites on September 10,1980, from 5 sites in April 1981 and from 2 sites in September 1981. No carbaryl was applied during 1981.

Dispersal in the Livingston Almond Orchard-1981

About 350 carbaryl-resistant M.occidentalis females, reared on pinto bean plants in a University of California, Berkeley greenhouse with T.urticae as prey, were released into an almond orchard near Livingston, California. Cut bean plants were placed into the crotch of every third tree every third row on June 9, 1981.Carbaryl was applied in May and on July 3. The second carbaryl application was combined with propargite (367 gram 30 WP Omite/hectare). A second propargite application at the same rate was made on July 21. The almond trees in this 36 hectare orchard are about 10 years old, spaced 4.6 meters apart in rows 7.6 meters wide and their canopies touch.

Leaf samples (10 leaves/tree) from 10 release (R) and 10 nonrelease (NR) trees were taken periodically, and counted as described above. M.occidentalis was sampled from 8-10 trees (including both R and NR trees at ground level and at the tops of the trees by using a pole pruner during July. The two colonies were tested with carbaryl. The samples were taken at the two heights because the pesticides had been applied by a ground rig and the tops of the trees were poorly covered. Another colony was collected and tested for carbaryl resistance in September 1981.

On July 31, two towers 3.4 meters high were placed 7.6 meters outside the east end of the almond orchard about 0.6 meters up a levee. The tops of the towers were thus 4 meters above the orchard floor. Each tower had 3 plastic panels (23 X 30 cm) at three heights, "low", "middle", and "high", that were thinly coated with high vacuum grease (Dow Corning) on the side facing the almond orchard. After removal from the towers, the panels were scanned with a dissecting microscope and the number of spider mites and predators were estimated by counting sections (2.54 X 30.5 cm) totalling 1/9 of the panel area. Samples of the phytoseiids on the panels were removed, cleared, and slide mounted for identification of species and stadium.

Results and Discussion

Bakersfield Almond Orchard

The carbaryl-resistant *M.occidentalis* released in August 1979 into Block I-A established, overwintered, survived a carbaryl application in July 1980, multiplied, and spread (Fig. 1). Sometime between August 1979 and July 15, 1980, the carbaryl-resistant strain in Block I-A reached Block II-B. Since Block II-B was not treated with carbaryl in 1979, carbaryl-susceptible *M.occidentalis* were abundant in this block (Hoy, Unpubl.), and the carbaryl-resistant strain must have interbred with susceptible natives. Carbaryl-resistant *M.occidentalis* were sampled in Block II-B on July 18, only 3 days after carbaryl was applied (Table 1) and when samples of *M. occidentalis* were taken from 7 sites in September 1980, the percentage of females surviving ranged from 24 - 80 % (Fig. 1, Block II-B). These moderate to high survival rates support the hypothesis that the resistant predators had interbred with natives; survival of females from resistant and susceptible laboratory colonies averaged 80 and 2 %, respectively. Carbaryl resistance in this strain is determined by a single major semidominant gene (Roush and Hoy 1981a).

The carbaryl-resistant predators survived a second winter in this orchard, as *M.occidentalis* collected in April 1981 were carbaryl resistant (Fig. 1). Predators collected in September 1981 were still carbaryl resistant despite the fact that no carbaryl was applied to either Block I or II during 1981 (Fig. 1).

The rapid spread of carbaryl resistant *M.occidentalis* from the release site (Block I-A) to Block II-B was unexpected and suggested that aerial dispersal could have occurred (Fig. 1), although since the trees are large and their canopies touch, it is possible that the predators were able to walk from tree to tree.

Livingston almond orchard

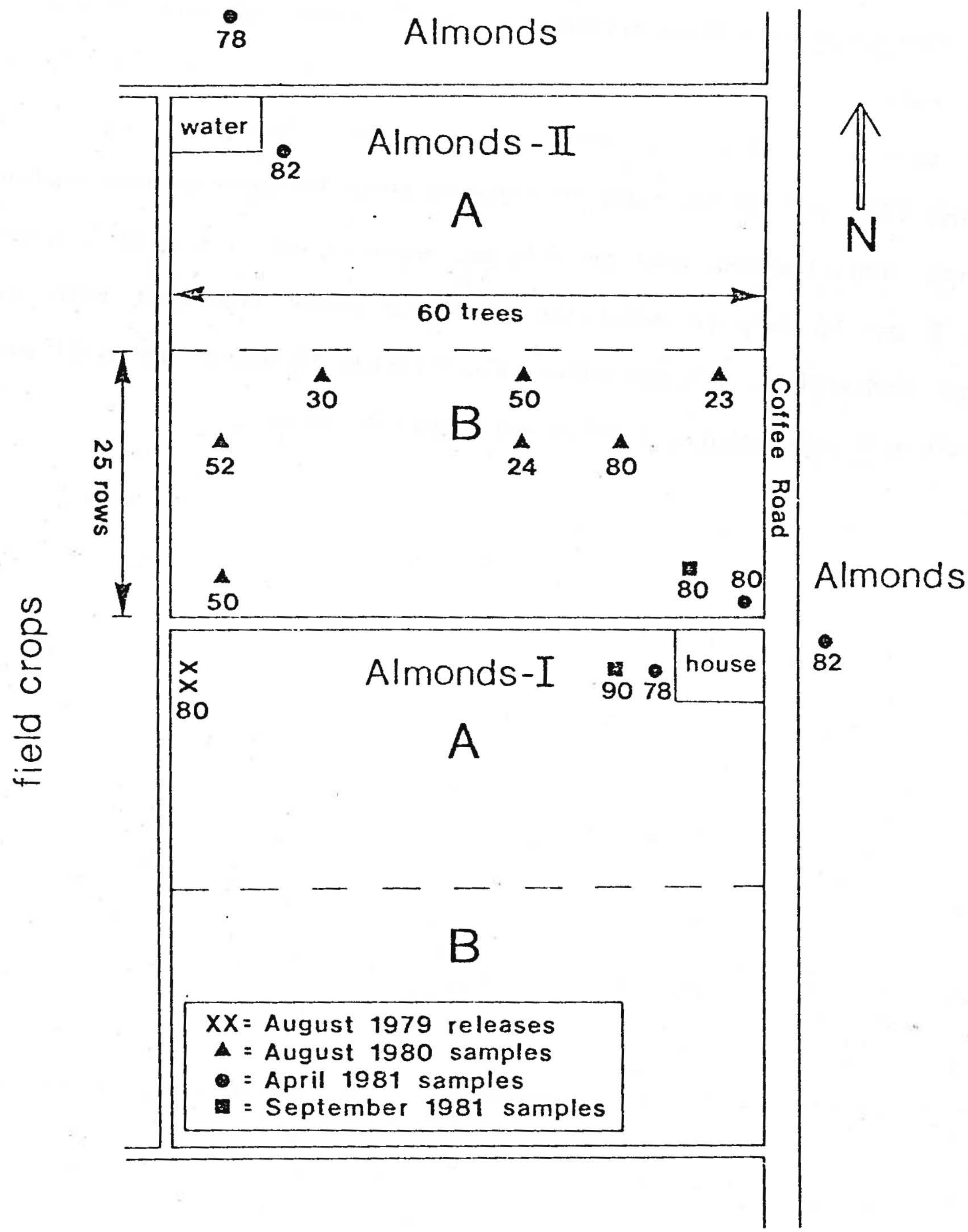
That the carbaryl-resistant M.occidentalis strain can disperse rapidly was demonstrated again in 1981 in the Livingston almond orchard. Predators were released on June 9, and were present by July in both the R and NR trees (Table 2). The 2 colonies obtained in July from the ground and tree top levels gave 97 and 40% survival, respectively, while a susceptible and resistant laboratory colony tested at the same time had 65 and 0% survival. Since the NR trees constitute 89% of the trees in the orchard, substantial movement within the orchard had occurred by July 17 (Table 2). The higher survival rate of the predators from the ground level supports the hypothesis that carbaryl coverage was better there. Spider mite densities increased during July and leaf damage was evident; unlimited food was thus available to M.occidentalis and extensive multiplication occurred (Table 2).

During July, spider mites began to disperse aerially from the orchard due to deteriorating foliage conditions and large numbers of spider mites were trapped on the sticky panels in late July and early August (Table 3). All M.occidentalis recovered on the sticky panels were females; no males or immatures were recovered. The peak predator dispersal lagged slightly behind the peak spider mite dispersal (Table 3).

Croft and Barnes (1971) found intertree migrations were quite limited in populations of M.occidentalis in a southern California apple orchard. "Releases could be made into individual trees"...while "adjacent trees receiving dissimilar treatments were unaffected for a considerable period..." Because spread was so slow, they concluded that "the ultimate success of the genetic induction of the azinphosm-ethyl resistance into the native susceptible population is yet to be fully proved" (Croft and Barnes 1972).

The rate of dispersal and degree of interbreeding of native and susceptible and resistant M.occidentalis is of concern in the implementation of a genetic improvement project (Hoy 1979). If the predators are released into orchards or vineyards after the relevant pesticide is applied, establishment of strains carrying pesticide resistances determined by major dominant or semidominant genes occurs readily in that specific orchard. However, it is unclear how rapidly, how far, or how many of these resistant predators will disperse from the release sites, and how best to monitor or "manage" these resistant M.occidentalis in the recipient orchards or vineyards. During 1980 and 1981, a total of 85 hectares of almond orchards in the San Joaquin Valley of California received inoculations of the carbaryl--resistant strain of M.occidentalis. It will be interesting to determine whether these orchards will serve as foci for spread of the semidominant carbaryl resistance gene into surrounding orchards or vineyards. Careful monitoring around these release sites may resolve this question. It is clear, however, that M.occidentalis can disperse through the air and that dispersal within the orchard can be more rapid than believed formerly. Furthermore, these data indicate that this laboratory-selected strain has performed well in these field trials, confirming that genetic improvement of this biological control agent had been achieved.

Fig. 1. Establishment and spread of the carbaryl-resistant strain of M.occidentalis in a Bakersfield, California almond orchard. Predators were released in August 1979 into Block I-A, which had been treated with carbaryl during July 1979. Carbaryl was applied to Block II-B during 1979 and to II-A and II-B during 1980. No carbaryl was applied during 1981. Numbers next to circles, squares, or triangles indicate the % gravid females surviving 48 hours after treatment with 2.4 grams carbaryl A.I./liter water. Few females (0-5%) of carbaryl-susceptible M.occidentalis survive this carbaryl rate.



Almonds
78
water
Almonds - II
82
A
N
60 trees
25 rows
B
30
50
23
52
24
80
Coffee Road
50
80
80
Almonds
field crops
Almonds-I
XX
80
90
78
house
82
A
B
XX= August 1979 releases
▲ = August 1980 samples
● = April 1981 samples
■ = September 1981 samples

Table 1. Establishment of the carbaryl-OP resistant strain of *M. occidentalis* in Block II-B of the Bakersfield almond orchard.

	Mean mites[a/] per leaf on trees treated with propargite at							
	600 grams[b/]		240 g[b/]		120 g[b/]		Check 0 g[b/]	
Sample dates-1980	Spider mites	*M. occ.*	Spider mites	*M. occ.*	Spider mites	*M. occ.*	Spider mites	*M. occ.*
June 13	0.01	0	0.02	0	0.01	0	0	0
July 2	0.24	0	0.03	0.0	0.02	0.02	0	0
	July 15-Carbaryl applied to all trees							
July 18	0.26	0.17	0.63	0	0.49	0.01	0.22	0
July 28	1.23	0.15	1.73	0.03	1.39	0.05	1.47	0.07
	July 29-propargite applied							
August 1	0.09	0.02	0.09	0	0.26	0.16	0.70	0.03
August 19	0.76	0.16	7.66	0.65	4.06	0.82	21.33	0.89
September 2	1.75	0.68	1.15	1.50	1.13	0.95	2.80	1.71
September 16	0.10	0.44	0.10	0.35	0	0.34	0.10	0.63

a/ Spider mite were *T. urticae* and *T. pacificus*.

b/ Six replicates of 4 trees each were sampled.

Table 2. Spider mite and M. occidentalis densities on foliage from the Livingston, CA almond orchard.

	Mean mites (all stages)/leaf[1/]			
	Release trees		Nonrelease trees	
Sample dates - 1981	Spider mites	M.o.	Spider mites	M.o.
June 9 Prerelease sample[2/]	0.7	0.02	0.2	0.01
July 3 carbaryl & propargite applied	-	-	-	-
July 8	4.5	0.10	3.9	0.03
July 17[3/]	4.3	0.61	6.4	0.26
July 21 propargite applied	-	-	-	-
July 27	10.0	2.4	6.3	0.62
July 31	8.0	1.5	6.0	0.98
Aug. 6	5.0	3.3	5.3	1.20
Aug. 20	0.03	0.6	0.04	0.43
Aug. 28	0.01	0.5	0.03	0.34
Sept. 17	0	0	0	0

1/ Based on 10 brushed leaves/tree; 10 R and 10 NR trees were sampled.

2/

3/ Two colonies of M. occidentalis were obtained and tested in the laboratory for carbaryl resistance.

Table 3. Aerial dispersal demonstrated in recoveries of *M. occidentalis* and spider mites from sticky panels[1/] placed at 3 heights on 2 towers located 7.6 m outside the Livingston, CA almond orchard.

Sample interval	Species	Mean no. mites[2/]/panel on					
		South tower			North tower		
		low	middle	top	low	middle	top
1981							
July 31-Aug. 6	spider mites	733	1125	1390	661	1305	1224
	M.occidentalis	5	14	0	0	27	8
Aug.8-Aug.20	spider mites	792	603	729	1098	909	1107
	M.occidentalis	36	63	27	135	117	90
Aug.20-Aug.28	spider mites	9	9	54	18	18	45
	M.occidentalis	36	27	27	27	72	45
Aug.28-Sept.17	spider mites	0	0	0	0	0	0
	M.occidentalis	0	0	0	0	0	0
Sept.17-Oct.1	spider mites	0	0	0	0	0	0
	M.occidentalis	0	0	0	0	0	0

1/ Panels were 23 x 30 cm in size and lightly coated with high vacuum grease (Dow Corning[R]).

2/ Numbers are estimates for entire panel.

Acknowledgements

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VI - Production of "Super Mite" for 1982 Releases

The predators released to date have been OP-Sevin or OP-permethrin resistant. The genetics of both Sevin and permethrin resistances are known (Hoy & Knop 1981; Roush & Hoy 1981a). Sevin resistance is determined by a major dominant gene. Permethrin resistance is determined by several genes.

A strain resistant to permethrin-Sevin-OP insecticides was produced during 1981 (Table VI-1). It should be mass reared and field tested during 1982.

Selection of immature predators with permethrin continued (Table VI -2); no big increases in resistance occurred.

New colonies of M. occidentalis continue to be screened and selected for permethrin resistance. One colony looked promising when it was screened at a very high level (Table VI - 3). However, the resistance is probably not determined by a major gene and there is no good increase in resistance level in this colony, so it will be dropped.

Table VI-1 .Responses to selection by M. occidentalis in 1981 of the "Supermite II" strain - Resistance to Sevin, OPs, and Permethrin in one strain.

Date 1981	Pesticide tested (g AI[a/])	# ♀♀ tested	% survival	% survival of controls	
				susc.	resist.
Jan 19	permethrin (2)	1225	53	10	87
Jan 23	carbaryl (2.4)	420[b/]	65	0	80
Feb. 2	permethrin (2)	240	72	0	30
Feb. 6	permethrin (2)	410	50	0	60
Feb. 13	carbaryl (2.4)	970	46	0	70
March 2	permethrin (2)	660	76	7	75
March 6	carbaryl (2.4)	380[b/]	63	17	73
Apr. 6	permethrin (2)	540	78	7	83
Apr. 10	carbaryl (2.4)	350[b/]	82	7	93
June 1	permethrin (4)	520	56	0	76
June 5	carbaryl (2.4)	210[b/]	76	0	73
Aug. 17	permethrin (4)	767	67	0	87
Aug. 21	carbaryl (2.4)	396[b/]	72	0	83
Sept. 24	permethrin (4)[c/]	610	70	0	77
Sept. 28	carbaryl (2.4)	1120	83	3	90

a/ Dose for permethrin is in g AI/100 liter and for carbaryl is in g AI/liter.

b/ Females tested with carbaryl had survived the permethrin treatment.

c/ Females tested with permethrin had survived the carbaryl treatment.

Table VI-2 Continued selection progress with M. occidentalis (Immature Selection) during 1981.

Selection no.	Date 1981	tested	Dose permethrin (g AI/100 l)	No. tested	% survival	Controls % survival Susc.	Resist.
31	30 Jan	♀	4	480	58	0	47
32	-	-	-	-	-	-	-
33	14 July	♀	4	520	41	-	-
34	31 Aug.	immatures	2	825	15	-	-
35	16 Oct.	♀	2	80	88	17	85
			4	80	84	12	73
	4 Nov	♀	4	480	66	0	70
		immatures	2	550	36	-	-

Table VI-3 Results of selection for a dominant pyrethroid resistance in a new colony of *M. occidentalis* from Washington (Dom?).

Date	Permethrin dose (g AI/100 1)	No. ♀♀ tested	% survival	Controls susc. colony	Controls resistant colony
24 Oct. 1980	4	1460	11.6 (A)	0	74
5 Nov. 1980	4	340	12.4 (B)	-	-
26 Nov. 1981	4	220 (A)	23	0	60
	4	83 (B)	13		
23 Feb. 1981	4	125 (A)	2	-	-
	4	165 (B)	19		
24 Apr. 1981	4	100 (A)	35	0	-
	4	100 (B)	39		
	4	100 (B)	31		
6 May 1981	4	100 (A)	26	-	-
	4	77 (B)	27		
	4	100 (B)	28		
27 July 1981	4	480 (A)	19.2	-	-
30 July 1981	4	330 (B)	6.1	-	-
5 Aug. 1981	4	240 (B)	17.1	0	50
10 Aug. 1981	4	231 (B)	34.6	0	55
8 Sept. 1981	4	20 (B)	55	0	68
23 Sept. 1981	4	320 (B)	33	0	75

VII - Releases of a Mite Parasite of Ants

Two releases of Pyomotes tritici, a parasite of insects, were made during 1981. This mite was easily reared in the laboratory on cigarette beetle pupae and on honey bee pupae. Only the number of suitable hosts limits production, and the availability of a cheap, effective artificial diet (Bruce, personal comm.) will make mass-rearing this parasite easy.

Southern red fire ants were brought into the laboratory several times. The mites successfully paralyzed and killed all stages but they developed well only on the ant pupae and larvae.

One release was made in late June into an ant control plot set up by Walt Bentley and Wilbur Riel near Bakersfield. About 2 tablespoons of cigarette pupae were released at each marked mound in the evening. The ants were active and quickly carried the beetle pupae containing the mites down into their nests. However, nut damage due to ants in the mite release area was nearly as high as in the untreated checks, so we have no evidence the mites are being effective. The plot will be monitored again in the spring.

The mites were also released into the eivingston almond orchard in August. No efficacy data were taken. The ant mounds will be examined next spring.

The parasitic mite colony is being maintained and if the release sites look promising next spring, additional releases can be made.

VIII Publications

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Agricultural Experiment Station
Division of Entomology and Parasitology

Berkeley, California 94720

November 11, 1981

Mr. Dale Morrison
Almond Board of California
P.O. Box 15920
Sacramento, CA 95813

Dear Dale:

Enclosed are 2 copies of the 1981 research report. I have sent copies to: M. Barnes, D. Rice, R. Coviello, F. Zalom, B. Barnett, W. Bentley and L. Hendricks, C. Dowing, E. Serber, R. Grigg and T. Browne.

If you have questions, please contact me at (415) 642-3989.

Sincerely,

Marjorie

Marjorie A. Hoy,
Associate Professor

MAH:fk
Encl (2)

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