Large-scale releases of pesticide-resistant spider mite predators

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Research also showed for the first time that mite predators "planted" in almond orchards can disperse aerially.

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 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 nonresistant predators were removed. Each strain was maintained on separate benches in the greenhouse.

Low rates of acaricide (Omite 30 WP, ⅓ to ½ pound per 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 stabilized 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, and 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 cannot 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 throughout 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

Above: Mite predators were released in orchard at right but not in defoliated trees.

Left: Spider mite webs indicate severe damage in almond trees.

Below: Researchers check soybean nursery field where 62 million predators were reared for release in almond orchards.

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 (½, 1, or 2 pounds 30 WP per acre) or Plictran (½ 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. Selection for dominant resistance genes will be slower in native spider mite populations if acaricides are used infrequently and at low rates. Plictran resistance has been found recently in spider mites in Oregon pear orchards (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 throughout 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, every

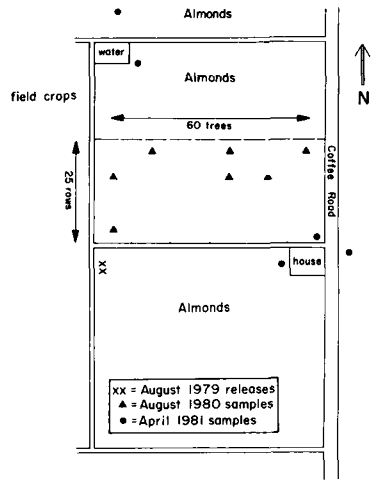

Fig. 1. Carbaryl-OP-resistant *M. occidentalis* were released in 80-acre orchard, 1979. Resistant predators were recovered in 1980 and 1981, indicating extensive movement.

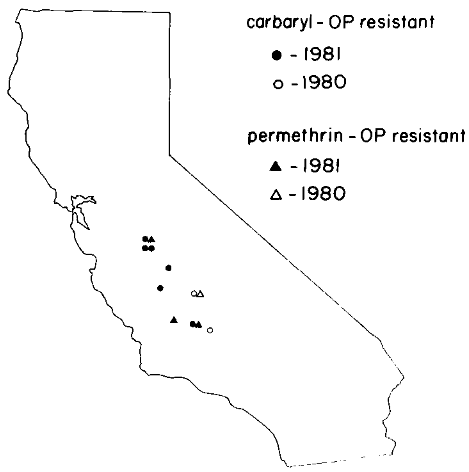

Fig. 2. Dispersal of two resistant *M. occidentalis* strains from almond orchards where releases were made in 1980 and 1981.

third row, in an almond orchard (Livingston-I 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 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.

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Resistant *Metaseiulus occidentalis* releases in almonds during 1981

Orchard location	Acreage	Strain released	Release date	Release pattern	No. females released/ tree*	Total females released	No. bands†
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	1,000	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	2,900	175,000	40
Hwy. 46 & 43, Block 32-4 Blackwell Corners	60	Permethrin-OP	Aug. 5	3rd tree 3rd row	350	165,000	100

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