Sampling *Tetranychus* spider mites in almonds

Frank G. Zalom □ Lloyd T. Wilson □ Marjorie A. Hoy
William W. Barnett □ Janet M. Smilanick

Six species of spider mites are associated with almond trees in California's Central Valley. The lack of economical and reliable sampling techniques has hampered not only research on these mites but also the grower's ability to estimate control status or population density in a minimum amount of time.

Three of the six spider mite (tetranychid) species — the European red mite, brown almond mite, and citrus red mite — are occasionally abundant enough to require chemical treatment. European red mite and brown almond mite are most often found in the northern and central Valley, and the citrus red mite, in citrus-producing areas of the southeastern Valley.

Three web-spinning species, however, reach high populations annually in many areas: the two-spotted spider mite, *Tetranychus urticae* Koch; the Pacific spider mite, *T. pacificus* McGregor; and the strawberry spider mite, *T. turkestani* Ugarov and Nikolski. Infestations are usually more severe in the southern than in the northern Valley. A substantial portion of the almond acreage in the Valley receives foliar treatments for control of these mites. Most treatments are made when infestations begin, usually in late June or early July.

Counting small and often abundant organisms like mites is time-consuming. Also, some conventional techniques, such as using the mite brushing machine, may destroy some of the mites and bias the population estimate. Our principal objective in this study was to develop a practical sampling scheme for web-spinning (*Tetranychus*) mites in almond orchards.

An alternative to counting each individual is presence-absence sampling, in which each sample unit, in this case a leaf, is examined for the presence of one or more individuals of a particular species, not for the number present. Based on an intrinsic relationship between the proportion of infested sample units and the density of individuals of a species on the sampled leaf, the population density of the species or need for control can be assessed.

Sampling time can be further reduced through sequential sampling in combination with presence-absence sampling. Sequential sampling involves examining leaves until a specified decision level, treat or don't treat, is reached. This scheme is generally more efficient than other techniques, but is especially so when population densities are either high or low.

Information required to develop a quantitative presence-absence sampling plan includes distribution of mites on a tree, the relationship between the proportion of the leaves infested and the average number of mites per leaf, a provisional control action threshold, and a measure of acceptable risk and sampling time (cost).

Within-tree distribution

To determine distribution within the tree, we sampled one orchard in Sutter County (Yuba City) and one in San Joaquin County (Highway 132) in 1977 and two Kern County orchards in 1978. The three web-spinning mite species were present in all orchards, but the predatory mite *Metaseiulus occidentalis* (Nesbitt) was only in the Kern County orchards (Bidart and Blackwell).

In 1977, we sampled 25 leaves from each of the four quadrants and the center of the tree for the lower and upper locations of each tree, totaling 10 areas per tree. In 1978, we examined 30 leaves at random from the outer area of each tree, sampling 4 to 18 trees in each orchard on 7 to 11 dates. Over 32,000 almond leaves were examined by binocular scope during the two-year experiment, and the mites (all stages) on each leaf were counted.

TABLE 1. Web-spinning (*Tetranychus* spp.) mites found in each portion of sampled trees in two orchards, 1977

Location in tree	Mites in orchard*	
	Highway 132	Yuba City
Quadrant:		
North	50.4	3.7
South	35.8	4.0
East	46.6	6.0
West	8.7	6.4
Center	32.3	6.8
Lower	16.4†	5.5
Upper	53.1	5.3

* Mean number of *Tetranychus* spp. per 25 leaves (averaged by sampling date). Highway 132 orchard was sprinkler-irrigated; Yuba City orchard was not.
† Differences between means were found by comparing the lower and upper parts of the trees at Highway 132.

Analysis of the data obtained from June onward indicates that the web-spinning mites are distributed randomly in the tree, except when disturbed by sprinkler irrigation. Table 1 shows a typical distribution for a non-sprinkler-irrigated orchard (Yuba City), and an orchard where sprinkler irrigation hitting trees (Highway 132) reduced the number of mites in the west quadrant and the lower location of the trees.

Clumping pattern of mites

Using the previous data, a second set of analyses determined the mites' clumping pattern per leaf, as affected by mite density, orchard, and the abundance of *M. occidentalis*. Clumping was expressed as the relationship between the percentage of leaves infested with mites, the corresponding density of mites per leaf, and the variance of mite densities per leaf.

In the presence of predatory mites, the web-spinning mites are less clumped (fig. 1). In other words, when predaceous mites are present, there are fewer spider mites per leaf for a given percentage of leaves infested with spider mites. To make sure that the greater

TABLE 2. Comparison of clumping coefficients for a single leaf sample unit for *Tetranychus* spp., 1977 and 1978 data sets

Orchards	Predator presence*	Clumping coefficients for *Tetranychus* spp. a	b	n†	r^2
Sutter and San Joaquin County	−	20.793	1.626	57	0.928
Kern County	−	19.513	1.631	77	0.571
Kern County	+	6.005	1.566	175	0.908

* Presence of *M. occidentalis*: − = not present; + = present.
† n = the number of 25-leaf samples.

clumping without *M. occidentalis* was not due to some intrinsic difference between the Kern County orchards and the more northern San Joaquin and Sutter County orchards, two coefficients, which together describe the clumping

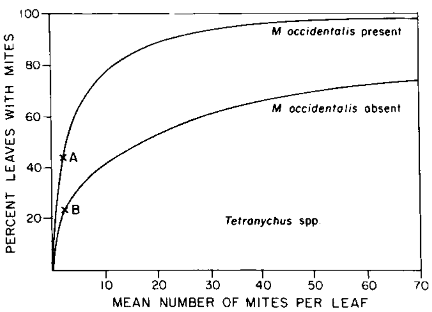

Fig. 1. Provisional control action threshold is higher with predators present (A) than without predators (B) in almonds.

pattern, were estimated for all orchards. These coefficients, called "a" and "b," represent the degree of clumping for the spider mites and are easily estimated using regression programs on the Statewide Integrated Pest Management (IPM) Project computer system. The Kern County orchards were also analyzed separately for those samples with the web-spinning mites but no *M. occidentalis* and for those with both the web-spinning and the predatory mites (table 2). The values for the "a" coefficient for spider mites in the absence of the predators for both areas were about 20, as compared with 6 when predators were present. The "b" coefficients were also higher in the absence of predators. These values reflect the biological significance of predation on the pattern of spider mite clumping: predation reduces the value of both coefficients, with "a" being reduced the most.

Provisional control threshold

Little is known about the maximum levels of mites that can be tolerated in most crops without economic loss. Web-spinning mite injury is related to many variables, whose influences are difficult to estimate. This is especially true of perennial crops such as almonds, where economic damage is usually not expressed until the year following injury. Quantifying the sustained physiological effects of mite feeding in such situations is difficult because of problems in controlling the environmental influences acting on the orchard over an extended period. At present, no control action thresholds based on the physiological effects of mite feeding have been developed for almonds.

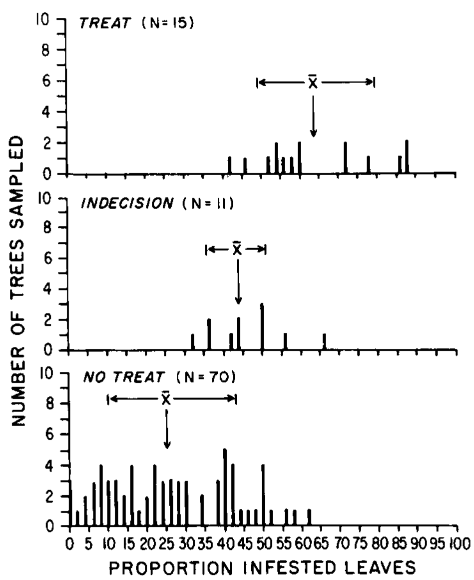

Fig. 2. Percentage of leaves infested with *Tetranychus* mites in relation to control decisions made just before sampling including mean and standard deviation for each action.

During the summer of 1982, we monitored three orchards weekly until an acaricide was applied. The orchards were near Livingston (Merced County), Three Rocks (Fresno County), and Madera (Madera County). Five trees in both the Livingston and Madera orchards and 10 trees in the Three Rocks orchard were tagged for subsequent sampling. To ensure coverage of the orchard, we chose the sample trees at random, but excluded young or obviously weak trees.

Each week we observed individual trees for general appearance, webbing from mite activity, abundance of the web-spinning mites, and predatory insect and mite distribution. Based on the potential for leaves to drop as a result of mite feeding, we determined whether: no treatment was necessary (low potential for leaf fall), a treatment was needed immediately (high potential), or no decision could be made using imminence of defoliation as the criterion. After these observations, we sampled 50 leaves at random above the sprinkler line from the circumference of each sample tree and examined them with a hand lens for presence or absence of all stages of the web-spinning mites and *M. occidentalis*.

Figure 2 shows a relationship between the percentage of leaves infested with the web-spinning mites and control decisions. The "N" values in the figure represent the number of times that treat and no-treat decisions were reached, and that a decision was not reached. The mean percentages of leaves infested with web-spinning mites for the three categories of decisions were significantly different from one another. Further, only one data point for the "treat" decision was below the mean percentage of infested leaves for the "indecision" criteria (44 percent).

Without a suitable control action threshold for web-spinning mite injury to almonds, we will develop sampling rules based on 44 percent (mean percentage of infested leaves) as a provisional threshold when the predatory mite *M. occidentalis* is present in an orchard. We are assuming that, if the percentage of infested leaves exceeds this value, premature leaf fall resulting from the feeding of web-spinning mites will result in significant crop loss and loss of tree growth in subsequent seasons. We are also assuming that the almond tree will tolerate moderate population densities without injury, as other studies have shown.

The provisional control action threshold of 44 percent (A in fig. 1) is equivalent to 22 percent (B) infested leaves in the absence of *M. occidentalis*.

Sampling

Integrated management of mites is feasible if trained personnel are available to evaluate changes in plant-feeding and predaceous mite populations and can recommend appropriate control measures when needed. The alternatives to a monitoring program are "preventive" acaricide applications, which may lead to resistance, resurgence, and secondary pest outbreaks, and "no intervention," which can lead to defoliation and subsequent crop loss.

Figure 3 presents our estimate of sequential sampling decision rules for web-spinning mites on almond when *M.*

occidentalis are present. Sampling decision lines comparable to those used in developing figure 1 can be derived using the sequential sampling program available on the Statewide IPM computer system.

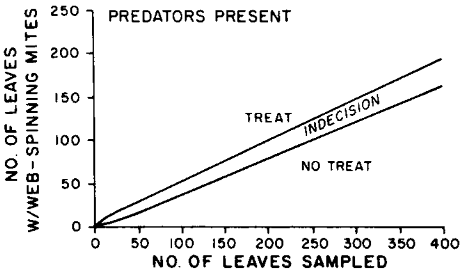

Fig. 3. Presence-absence sequential sampling decision guidelines for web-spinning mites on almond with predators present.

The actual number of trees sampled depends on an estimate of acceptable sampling time and knowledge of the minimum treatment area. Some areas within an orchard, such as those near roadways or on a streak of sandy soil, have greater potential for mite outbreaks than the rest of the orchard. If it is possible to treat only those areas instead of the entire orchard, they should be sampled separately. To reduce the effect of between-tree variance within an orchard, the number of leaves sampled from each tree should be reduced, thus increasing the number of trees sampled. At least five trees should be sampled from each orchard unit. Trees within each unit should be sampled at random, but the trees chosen should not be obviously different from others in the unit.

The leaves chosen are selected at random around the circumference of the tree above the sprinkler line. Each leaf is examined only for the presence or absence of any life stage of the web-spinning mite species. Actual mite numbers per leaf or presence or absence of damage is not important.

Monitoring in almonds

Early in the season, mites are concentrated on the tree's lower portions and centers. Later, they disperse to the outside of the tree and become uniformly distributed. After early June, leaves removed randomly from any portion of the tree above the sprinkler line will provide an accurate estimate of web-spinning mite abundance.

Monitoring should begin in early June with random sampling of leaves for predators, including those other than M. occidentalis, such as Stethorus spp., lacewings, and six-spotted thrips. Predatory mites are most often associated with colonies of spider mites. Their presence should be considered before any pest management action is taken, because the predators may reduce web-spinning mite populations. The presence or absence of M. occidentalis will determine which sampling decision rules to use.

When either a "treat" or "no-treat" decision is reached, sampling can stop. If no decision can be reached, sampling should continue as long as time permits.

The presence-absence sequential sampling plan provides an estimate of whether or not a treatment is required, and can be used as part of a weekly orchard monitoring program. The sampling plan could prove valuable when used after mid-June in orchards where mites may become a problem because of cultural practices, insufficient predators, or pesticide intervention. Presence-absence sampling should follow an early-season program of monitoring densities of web-spinning and predator mites and applying low rates of acaricides when necessary to reduce high infestations.

Frank G. Zalom is Integrated Pest Management (IPM) Specialist, Cooperative Extension, University of California, Davis; Lloyd T. Wilson is Associate Professor of Entomology and Associate Entomologist in the Experiment Station, UC Davis; Marjorie A. Hoy is Professor, Department of Entomological Sciences, and Entomologist in the Experiment Station, UC Berkeley; William W. Barnett is Area IPM Specialist, Cooperative Extension, Fresno County; and Janet M. Smilanick is Post Graduate Researcher, Department of Entomology, UC Davis. *The authors gratefully acknowledge the assistance of Peggy Kaplan.*

Under projected interest rates, plantations wouldn't be profitable on low-quality sites

Blue gum plantations analyzed for economic return

James A. Rinehart □ Richard B. Standiford

Increased demand for firewood and a growing market for hardwood fiber have created interest in planting eucalyptus in California, prompting this assessment of growth and potential economic return for eucalypt plantations. We have developed a variable site-density growth model for blue gum, *Eucalyptus globulus*, and have used the yields predicted to evaluate blue gum plantations under certain cost and revenue assumptions. From such information, we have derived the optimum number of trees and rotation length under different management conditions.

Growth and yield model

A 1929 University of California publication by Woodbridge Metcalf presents data on 96 blue gum stands throughout California. From this information, he constructed site class curves to predict soil productivity and presented empirical yield tables for three site classes. Using modern computer techniques not