Despite some data gaps, as in the OFM model, this technique has some application now.

San Jose scale infestations as extensive as this one on almond twig cause large losses of bud and fruit wood and culling of fruit. Above right, adult male has characteristic black bar across thorax, long antennae in relation to body, and small head and eyes. (10×)

Monitoring and modeling San Jose scale

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San Jose scale, *Quadraspidiotus perniciosus* (Comstock), is one of the world's most severe pests of deciduous fruits and nuts. This insect arrived in the United States from the Orient in about 1870 and was first reported damaging fruit trees in California in 1873. Although several parasites and predators attack San Jose scale (SJS), economic control has depended on insecticides. Chemical controls usually include dormant sprays of organophosphate insecticides and/or narrow-range oils, or foliar sprays directed against immature (crawler and white cap) stages in the spring and early summer.

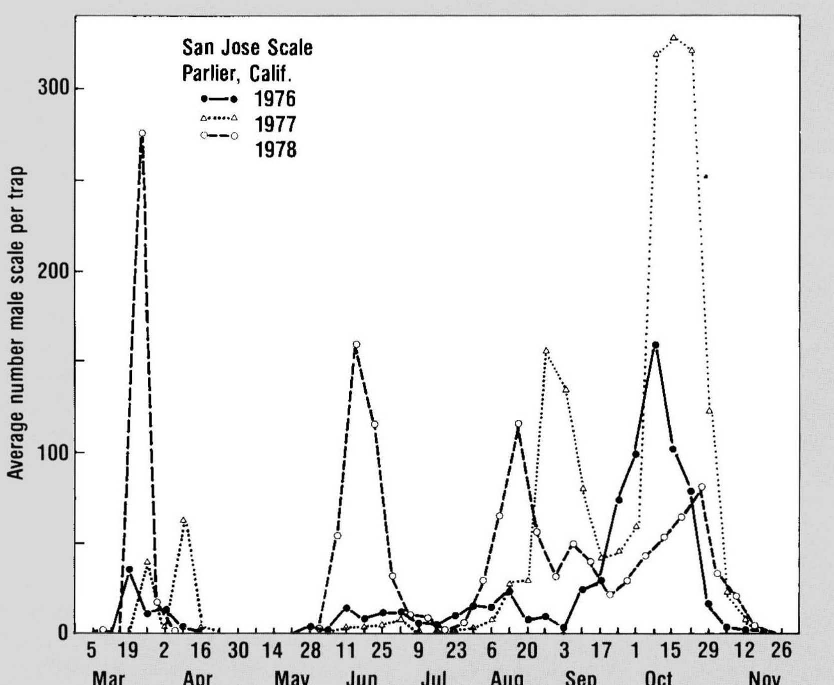
Timing of dormant treatments is usually not too difficult; timing of sprays for crawler activity has sometimes been inaccurate. In recent years advances have been made in our knowledge of San Jose scale behavior that should lead to improved control strategies and management of this pest, particularly in situations where dormant sprays have not been used. This report presents some of the new techniques and discusses how they can be used to develop pest management programs in deciduous orchards.

In 1973 the presence of a sex pheromone in San Jose scale was confirmed; researchers at Cornell University identified and synthesized the pheromone in 1977-78. With the availability of a synthetic pheromone, techniques for monitoring scale populations were soon developed for field use. The Zoecon SJS "tent" trap used for San Jose scale is different from those used for Lepidoptera species but has a rubber dispenser (cap) similar to other pheromone dispensers.

For routine monitoring, tent traps are placed about 6 to 7 feet high in the north or east sides of host trees. They must be securely fastened with a wire hanger to a tree limb to prevent them from being blown out of the tree by the wind. At least three traps should be used for monitoring San Jose scale, regardless of orchard size. In orchards larger than 30 acres, one trap per 20 acres is recommended.

Traps should be inspected twice weekly for male scale and cleaned, particularly in early March when collection of first males is important in using the scale phenology model to time subsequent crawler emergence. Traps should be replaced whenever they become too dirty for accurate identification and counting of male scale; pheromone caps should be replaced every six weeks. Care must be taken to correctly identify male scale collected because of their small size.

With this trapping system, male San Jose scale flights and population trends can be monitored relatively well (see graph). For detection of scale infestations in deciduous orchards, the traps offer an early-warning



Seasonal flight trends of San Jose scale males collected in pheromone traps. In short spring flight (March) most males may be trapped on only three or four days.

Day-degree requirements for development of life stages of San Jose scale*

	Day-degrees	
Stage	Male	Female
Embryo (egg) development	405	421
First instar (crawlers, white caps, black caps)	318	331
Second instar	213	220
Pupal stages — males	95	
Tight cap — females		58
Pre-mating adults	19	20
Average D°/generation	1050	1050

*Lower threshold = 51° F; upper threshold = 90° F. The lower threshold is the temperature below which the insect's development stops; the upper threshold the temperature above which the development rate begins to decrease. The amount of heat between the two thresholds that is needed for the insect to develop from one stage to the next is calculated in day-degrees — the degrees of temperature above a threshold for each day.

alternative to laborious inspection of fruit wood or the even less desirable method of finding infested fruit. After the pheromone trapping system for San Jose scale was introduced, research cooperators in Utah and Michigan produced a phenology model for scale, using a large amount of California data. Early-season (first-flight) trapping data used in conjunction with the model should lead to improved timing of treatments for San Jose scale, particularly against crawlers in late April or early May. Using lower and upper threshold values of 51° and 90° F, respectively, the day-degree requirements as used in the model are given in the table.

The model accommodates three hypothetical types of growth curves for San Jose scale. In the first cycle or generation curve that we might expect to see for San Jose scale, only overwintered black caps (late first-stage scale) would be producing new crawlers in the spring. This is the so-called early curve. Calculations show that, on the average, 225 D° were required for scale development from January 1 to the point at which first males were observed in pheromone traps, with an early population curve. However, the model projects that 274 D° are required, on the average. Similarly, development from first male flight in the spring until first crawlers were observed required approximately 323 D°. The model projects a day-degree requirement of 372°. Therefore, in the hypothetical early curve we see a rather wide divergence between observed events (first male, first crawler) and what the model predicts for these same events.

When we evaluated a so-called mid-curve, in which all stages (black caps, mature mated, and unmated females) of San Jose scale would be expected to survive the winter and produce individuals in the spring generation, we found a much closer correlation between observed events and what the model projected should happen. This was true for both time periods: from January 1 until first males were trapped, and from first males trapped until first crawlers were observed.

When the third hypothetical generation or growth curve was evaluated, in which only overwintered mature females would be expected to survive, we again found considerable variation between observed events in the field and those the model projected, particularly in the D° accumulations from first males until first crawlers appeared in the field. From a practical standpoint for California, the early or mid-curves would be the most realistic with regard to scale development.

In considering how the San Jose scale model can be used in pest management programs, application of chemical controls for scale crawlers in May would be one of the most critical areas to evaluate. Based on model projections, we would anticipate crawler emergence approximately 400 D° after the first males in any given generation have been collected in pheromone traps. As in the case with oriental fruit moth egg hatch, however, we suspect that spray timings at the very beginning of crawler emergence probably would not be optimum, but instead should be delayed for several days. This means that we could add approximately 100 to 150 D° to the crawler emergence curve beyond first crawler and spray at that point.

This approach to spray timing for San Jose scale needs to be verified with field plot work. However, as in the case with the oriental fruit moth model, we still feel that the model is sufficiently accurate to begin using it under a variety of pest control advisor and grower applications to challenge its validity and detect the weak points that undoubtedly exist.

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Field data indicate that natural populations of the two-spotted spider mite, *Tetranychus urticae* Koch, can decrease strawberry yields by 10 to 15 percent at various harvest periods during the season. Since 1964, entomologists at University of California, Riverside, have been conducting research to develop a practical program for managing the mite on summer- and winter-planted strawberries in southern California, studying the efficacy of predatory mites and selective miticides, as well as the injury caused by spider mite feeding. Effective control measures are being sought for incorporation into integrated programs in commercial strawberry plantings.

Photosynthesis and productivity

In California, commercial strawberry varieties produce fruit continuously throughout the winter and spring. Fruit filling and enlargement occurs when plant canopies are established and after the plant's initial storage reserves have been utilized. Carbohydrates and other materials migrating into developing berries originate predominantly in chlorophyllous tissues, and the relative quantity of nutrients available primarily depends on the rate of photosynthesis, in which sugars (photosynthates) are produced by the binding of carbon and water molecules into carbon-based chains. Photosynthesis occurs within the chloroplasts of leaf cells and is powered by solar energy absorbed by the pigment chlorophyll. The required water is brought up from the roots through the process of translocation. The second component, carbon dioxide, enters the leaf tissue through the stomata — small closable apertures in the epidermis. While stomata facilitate movement of carbon dioxide into the leaf, they also allow large quantities of water to be lost by evaporation to the atmosphere — a process known as transpiration. When transpiration rates exceed the rate of water uptake by the roots, the plant wilts.

Photosynthates are required for respiration and growth of vegetative structures (leaves, stems and roots) as well as for fruit production. By continuously producing new foliage, the plant replaces leaves that may die within several weeks after development.

Feeding by two-spotted spider mite causes plant stress, which detrimentally affects photosynthesis, transpiration, fruit production, and vegetative growth. Reductions in photosynthesis rates from mite-caused stress decrease berry production (fig. 1). The amount of stress and time of the season when stress occurs largely determine the extent of injury to the strawberry plant. Ideally,