

CITRUS PEST MANAGEMENT STUDIES IN TULARE COUNTY

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PROFITABLE CITRUS growing in the San Joaquin Valley involves successful risk analysis and the offsetting of perils resulting from overproduction, competition, frost, diseases and insect pests. Marketing difficulties are usually resolved through cooperative effort. Overcoming production risks requires problem-solving procedures applied to each orchard and crop.

The most frequent production hazards include crop damage from cold weather, tree and fruit losses from virus or fungus diseases, and fruit quality reduction from insect pests. The degree of risk posed by these hazards determines the amount of economic input that can be justified as corrective or preventive measures.

Applying principles of good business management in resolving these problems dictates that the greatest danger be insured against—before substantial expenses are incurred protecting against

lesser risks. For example, risk from frost damage exceeds all others combined. The cost of freeze protection is more expensive than the cost of control measures for diseases and insect pests. Unfortunately, only half of the citrus acreage has any type of frost protection (some of which may be classed as insufficient for the task) while nearly 100% of the trees receive various treatments for insect pests (a portion of which may be considered superfluous or excessive). An important principle to remember is that a grower is in the business of growing fruit—not killing bugs!

Overproduction

In all growing areas citrus production exceeds consumer demand. There is no shortage of fruit. Distribution of the crop is mainly concerned with how to handle volumes that are near surplus in a manner that minimizes the depression for the entire market.

Fresh fruit

Historically, 75 to 85% of navel orange production has gone into fresh fruit channels. Prospects for the future indicate a more realistic flow will be in the range of 60 to 70%. Valencia orange distribution faces a similar problem; 50% of the production is presently diverted away from fresh market outlets. Use of fresh lemons in both domestic and export markets accounts for less than 60% of the fruit grown. Yet 100% of the acreage, regardless of the market outlet, is managed under pest control programs designed to maintain or enhance fruit appearance.

The degree of risk from insect injury involving fruit appearance is not equal for all varieties. Certain pests are more harmful to some varieties than others. The development of an economical pest control program requires analysis of the market potential for the variety and the hazard posed by the various insects. As

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New Publications

SOYBEAN RESEARCH IN CALIFORNIA. Bul. 862. Soybean yield and other data from small plot and field-size experiments in California have been included in annual reports of various research organizations for over 50 years. However, these data are not generally available to the public. Even though there has been no sustained com-

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mercial production of soybeans in California, there is a continuing interest in the crop by farmers, oil mill processors, and consumer organizations. This bulletin summarizes the results of various soybean experiments in California and compares these results with data from other areas where the crop has been profitable to producers.

an example, valencias are not favored by citrus thrips to the same degree as are navel oranges, yet both are severely injured by red scale. These two varieties require a program that protects from red scale, but they have entirely different needs as regards thrips control.

Why is it necessary to maintain pest control programs designed primarily for fruit appearance when the anticipated volume going into fresh channels will only require from 50 to 60% of the fruit that is being grown? Is it good economics to treat fruit to enhance its appearance when nearly half of it will never be seen on the fresh market?

Pest problems and management

An increasing number of Tulare County citrus growers are seeking better ways to manage their pest control programs. These growers have a common complaint: "I am spending more and treating more, but my pest problems are getting worse." This is not uncommon in many crop situations in Tulare County. It had its genesis in pesticide programs that promoted resistance in insect and spider mite populations. The problem was compounded as the need for more treatments of primary pests magnified biological disruptions, and the necessity to treat secondary pests. Some citrus growers are now beginning to realize that they inadvertently stepped onto a pesticide treadmill.

Fortunately, the pesticide load in Tulare County citrus groves can be markedly reduced with good pest management, although it may not be easy. On the contrary, good pest management requires considerable time and effort. Mainly, it requires a change of attitude. Growers must refrain from thinking in terms of pest-free groves and think more in terms of treatment levels. They must adopt the attitude that a pesticide is a tool of pest management, not a panacea.

In good pest management programs, each individual grove is regularly assessed for pest population levels. Experience now suggests that scheduled treatments by calendar date or stage of growth are wasteful, and have a tendency to relax grower vigilance. Damaging infestations of secondary pests often flare up unexpectedly after applications of presumed clean-up sprays. It is poor pest management if treatments result in the trading of pests, especially if the new ones are more serious and costly to control. Spider mites are an example of this kind of secondary pest in many crops. It is often good management to accept the

presence of primary pests in low numbers, even if they cause a small amount of injury. In some cases, it is advisable to accept the increased risks because excessive treatments eventually make the pest more harmful. This is especially important where resistance is developing. Good pest management requires the more efficient use of pesticides and the maximum use of natural controls. If chemical control is necessary, the total insect and mite complex requires evaluation, to avoid upsetting predators and parasites of non-target pest species.

The ranking of pests of citrus in Tulare County depends upon the risks acceptable to management, and to what extent natural controls can be exploited. In minimally treated groves some pests are ranked low because their natural controls are reliable and treatments are usually unnecessary. In typically treated groves, natural controls of these same pests have often been disrupted and treatments are required. However, some pests in typically treated groves are ranked low because the many treatments for other pests suppress them. These same pests in minimally treated groves may require occasional treatments because natural controls are ineffective and treatments for other pests are too few to suppress them. The main question is whether a pest management program which exploits both natural and chemical control is in the long run more economical than one which depends almost entirely on chemical control.

Table 1 lists the pests most frequently found in citrus in Tulare County, and compares the relative importance in typically, and minimally, treated groves. Table 1 is only a broad generalization of the situation as it now exists in Tulare County. Moreover, as red scale continues to spread (see later discussion), pest and treatment priorities will change considerably in both minimally, and typically treated groves.

Citrus thrips

Thrips are rated high as pests in Tulare County. The fruit must meet marketing standards; too much scarred fruit results in heavy culling and reduced grade, both influencing grower profits. However, in many cases treatments for thrips are overdone, with unwise choices of chemicals. In their zeal to protect their fruit, growers frequently resort to multiple treatments, some of which include combinations of insecticides. Often, treatments are applied beyond the stage of fruit development susceptible to thrips

damage. Such treatment programs trigger biological upsets and promote resistance. Costly citrus red mite, brown soft scale, cottony cushion scale, or yellow scale treatments are likely aftermaths of thrips programs of multiple applications or combinations of insecticides.

In minimal treatment programs, citrus thrips populations are checked closely from the prebloom period until the fruit reaches walnut size. Extra close vigilance is maintained during the petal-fall period when fruit is most susceptible to damage; groves should be checked at least twice weekly during this period. In groves with historically light thrips injury, treatments are not made until a significant number of the outside fruit from a random sample show thrips activity. Experience has shown that citrus thrips may not require treatment in these groves.

In certain areas of Tulare County, thrips are a chronic problem and difficult to control. Groves in such areas showing less of the outside fruit with thrips activity may warrant treatment. Grove history will influence judgment. Prebloom treatment in troublesome groves has proven helpful. But the key to preventing excessive thrips scarring is repeated checking, not repeated treatments. Recently, it has been observed that certain organophosphate insecticides actually increased the thrips problem. Similar problems have been observed and recorded in Tulare County vineyards.

Cultural practices and varietal susceptibility may be important aspects of citrus thrips management. Growers have long recognized that valencia oranges experience fewer thrips problems than navel oranges—lemons even less. Observations in Tulare County have indicated that groves with cover crops or weedy growth have fewer thrips problems than groves under non-tillage and chemical weed control. Perhaps thrips populations are more stable in complex biological communities. Groves with ground covers do harbor a greater number and variety of arthropods. Higher humidities are generally found in groves with abundant vegetation which may unfavorably affect thrips populations. The habits of thrips on trees suggest that they favor exposed, dry conditions. Moreover, observations and limited experiments in Tulare County indicate that thrips are not economically important in groves irrigated by overhead sprinklers. How ground covers and modification of other practices may fit favorably into citrus culture and regulation of citrus thrips populations is currently under investigation.

Biological control of citrus thrips has been assumed to be negligible. But biological control may not need to be highly effective for economically beneficial results. For instance, recent observations and studies showed that citrus thrips are less of a problem in minimally treated groves than in those heavily treated. How much biological control contributes to this condition is not known. But it is significant that recent laboratory studies verified grove observations that predaceous mites prey (quite voraciously) upon citrus thrips. Predaceous mites usually abound in minimally treated groves, and are rare in those heavily treated.

Moreover, navel orange culling studies in the packinghouse revealed that the modest thrips injury experienced in untreated check plots (in these minimally treated groves) resulted in no economic losses. Light scarring by thrips has little effect on packout. The amount of fruit culled for other reasons (ice mark injuries, picking injuries, puffy fruit, disease injuries, etc.) is much more significant. In the case of valencias, the packout is more dependent on size, granulation, and regreening than on thrips scarring. The study clearly demonstrated the feasibility of establishing sound, economic levels for citrus thrips. But more importantly, the studies showed that many of the calendar types of treatments for citrus thrips control practiced in Tulare County are not economically justified.

Under minimal chemical programs, pesticides for the control of thrips are used selectively, or sparingly—especially contact insecticides. Botanical bait-insecticides (sabadilla and ryania) are the primary materials used. If they fail, or in situations where thrips are excessive or difficult to control, contact insecticides are used. If organophosphate treatments are necessary, follow-up treatments, if needed, should be botanical bait sprays. The key to effective bait spraying is surveying and treating to maintain populations below economic levels, particularly during the petal-fall period, rather than attempting to maintain thrips-free groves.

Citrus red mite

In groves receiving typical chemical treatments, citrus red mite becomes a costly pest to control. Red mite predator populations in these groves have been badly disrupted by pesticides. Growers are reluctant to tolerate even low populations of mites for fear of population explosions, which commonly occur in typically treated groves. Their problems

multiply with increasing red mite resistance to available acaricides.

Experience is showing that in minimally treated groves, under good cultural management, citrus red mite is seldom of economic importance. It appears that red mite population-increases in typically treated groves have a strong treatment-induced association. Studies and observations over five years showed that red mite populations, historically considered damaging, have little effect on the crop or tree vigor. In these minimally-treated groves, red mite populations are effectively suppressed by natural controls. The predaceous mite, *Amblyseius hibisci*, exerts considerable control of red mite populations during the spring. In late spring, red mite populations are often quickly decimated by a viral infection. Periods of high temperature and associated low relative humidity also suppress red mite populations. Knowledge that citrus trees tolerate high citrus red mite densities, and utilization of natural control factors can result in substantial savings in pest control costs.

Growers should understand why total reliance on chemicals for pest control is often self-defeating. Natural enemies are destroyed and spider mites commonly resurge to even higher levels after treatment. Thus, management problems are magnified. Developing resistance increases the dilemma. Good pest management seeks to minimize upsets and resistance by placing greater emphasis on economic thresholds and natural controls.

California red scale

California red scale is becoming the number one pest in Tulare County as it continues to infest more groves each year. All other pests seem minor by comparison. Red scale control requires the best in pest management. All too often timing of insecticide applications and spray coverage are inadequate for effective red scale control. Growers sacrifice coverage when they attempt to reduce costs by using lower gallonages. Application equipment is frequently inadequate or poorly calibrated.

In many typically treated groves, preventive sprays are commonly used during early spring (although not recommended). Frequently, these treatments overlap the bloom period, causing unnecessary honeybee kills. These preventive treatments are supposed to clean up scale infestations (armored and soft scale), while controlling thrips, aphids, and orangeworms (cutworms and fruit-tree leafrollers). One broad-spectrum in-

TABLE 1. COMPARATIVE RANK OF TULARE COUNTY CITRUS PESTS UNDER DIFFERENT REGIMES OF PEST MANAGEMENT

Minimum chemical programs	Typical chemical programs
Citrus thrips	Citrus thrips
Cutworms	Citrus red mite
Citricola scale	Brown soft scale
Red scale	Red scale
Citrus red mite	Cottony cushion
Katydid	Yellow scale
Fruit-tree leafroller	Cutworms
Leafhoppers	Fruit-tree leafroller
Aphids*	Leafhoppers
Yellow scale*	Aphids
Cottony cushion scale*	Citricola scale†
Brown soft scale*	Katydid†

* These insects are seldom specifically treated in minimally treated groves.
 † These insects are seldom specifically treated in typically treated groves.

TABLE 2. PEST TREATED, CHEMICALS APPLIED, AND COSTS PER ACRE IN THE ERIC MULLER GROVE, 1970 THROUGH 1972

Year	Pest treated	Chemicals applied	Cost/acre*
1970	Thrips	Sabadilla (twice)	\$20.00
1971	Thrips & katydids	Sabadilla Parathion	30.00
1972	Thrips	Sabadilla Ryannia	30.00
Three-year average cost/acre			\$26.70

* Includes application costs. Average cost of typically treated grove without red scale for the same three years in Tulare County is \$73.00/acre.

secticide combination used is malathion-parathion, an exceedingly potent mixture. Malathion is added because parathion does not control brown soft scale. An acaricide is sometimes added to prevent spider mite "explosion" which often follows these treatments.

Pest control problems should be managed individually. Economic control of thrips is best achieved at petal fall. Control of the armored scale (red and yellow) is best achieved with thorough coverage sprays during the post bloom period. Recent observations indicate that low populations of red scale are maintained with prebloom applications, but only with thorough coverage. Cutworms frequently pose problems during the bloom, but only emergency treatments are recommended and only in such a manner not harmful to honeybees. With careful checking, orangeworms are adequately controlled either before or after bloom. It is unlikely that aphids pose a serious problem in Tulare County (see below).

Red scale treatments under a minimum chemical program include non-oil and oil materials. Parathion alone will adequately control red scale in Tulare County, with proper timing and thorough coverage given prime consideration. The malathion-parathion combination is recommended only for cases of difficult-to-control red scale populations. Malathion has an adverse effect on predaceous mites and frequently causes a buildup of red mites. Curiously enough, predaceous mites survive parathion treatments. Thus, parathion alone best fits into a pest management program.

Petroleum oils are effective with thorough coverage. The use of oils in Tulare County is safest on lemons and valencia oranges. Navel oranges are considerably less tolerant and an adverse reaction to oil may occur—particularly when trees have been subjected to stress from soil moisture deficits during the irrigation season, or during prolonged periods of excessively high temperatures that produce greater demands on soil moisture and movement of sap in the tree, or with a poor or weak tree condition. Oil sprays demand that the orchardists coordinate grove operations (especially irrigation) with the treatment. The correction of soil management problems such as runoff, poor water penetration, and unhealthy root systems should be undertaken before adopting a petroleum oil spray program for red scale.

Biological control of red scale cannot be relied upon in Tulare County citrus groves at present. However, recent studies do show that the red scale strain of *Comperiella bifasciata* has been slowly making its way into commercial groves since the demise of the red scale eradication program. *Aphytis melinus* is being released and established in minimally treated groves. Both parasites control red scale in dooryard plantings of citrus. Whether this will occur in commercial groves remains to be seen. *A. melinus* appears more sensitive to the hazards of grove environments (pesticides, dust, etc.) than *C. bifasciata*. Recent studies have shown that the insecticides commonly utilized for pest control in minimally-treated groves had little effect on *C. bifasciata*. This is considered to result from proper timing and rates of application. For example, properly timed treatments for citricola scale, thrips, and cutworms using parathion as outside coverage sprays have not measurably disturbed *C. bifasciata* populations.

Recently, commercial entomologists in Tulare County with the help of the USDA tested the practicality of using virgin female red scales for population monitoring. The results have been exciting. For example, the traps intercept low populations of scale with minimal inspection time. Trapping shows promise as a means of quickly measuring the effectiveness of treatments.

Yellow scale, cottony cushion scale, and brown soft scale

Brown soft scale and cottony cushion scale are effectively controlled by parasites and predators; the parasite, *Metaphycus luteolus*, on brown soft scale and

TABLE 3. COMPARISON OF PACKOUT IN THE MINIMALLY TREATED ERIC MULLER GROVE WITH THE AVERAGE TYPICALLY TREATED GROVE IN THE IVANHOE AREA OF TULARE COUNTY, 1970 THROUGH 1972

	Muller			House Averages*		
	1970	1971	1972	1970	1971	1972
Juice	6	18	10	7	22	13
Packed fruit	94	82	90	93	78	87
Sunkist	92	91	95	94	88	93
Choice	8	9	5	6	12	7

* House average is given for the same week in which the Muller grove was picked.

Rodolia cardinalis (the vedalia lady beetle) on cottony cushion scale. Biological control of yellow scale is sometimes less effective, but adequate under most conditions. Border trees along hillsides often support high populations of yellow scale; apparently hot, dry conditions along these border trees are unfavorable for the yellow scale strain of *C. bifasciata*. Treatment of the border trees is usually not recommended as they serve as insectaries producing *C. bifasciata* for the rest of the grove.

Fortunately, the predators and parasites of these three scale insects are so effective that an occasional treatment with certain organophosphates for other pests causes little disruption. However, repeated treatments with these same chemicals frequently cause population explosions. Certain chemicals cannot be utilized in a minimum treatment program since even a single application results in severe biological disruption.

Leafhoppers

The majority of Tulare County growers whitewash their trees in the fall as a preventive repellent for potato leafhopper. It is questionable whether early harvested navels require treatment. We suggest that growers consider not whitewashing some of their early-pick acreage to determine whether leafhoppers are indeed a pest in their area.

Cutworms and katydids

These pests are rated much higher in minimally treated groves than in groves receiving typical chemical treatment (see table 1). Materials used for other pests in a typical control program suppress both insects, particularly the katydids. Under minimal treatment programs, neither is a pest in all groves every year. Not enough is known about the biology of the two insects to suggest why they periodically fluctuate above, and below economically damaging levels. Vigilance is important because direct crop losses result if treatments are not made when necessary.

Growers are urged to inspect their groves carefully from the middle of March through petal fall. The greatest

number of cutworms are found during this period. The University treatment level (10 cutworms per hour of search) is a good guideline for growers, but other management considerations are equally important. Treatment decisions are influenced by flowering and fruit set. For example, small numbers of worms may cause considerable damage in short flower years.

No treatment level has been developed for katydids. They are particularly serious after petal fall when they begin feeding directly on the fruit. A careful management decision is required at that time. A petal fall treatment for thrips with most contact insecticides is effective.

Cutworms and katydids are both effectively controlled by low rates of parathion. Only prebloom and petal fall treatments with parathion are recommended. Prebloom treatments are less disruptive than post-bloom treatments. Only emergency treatments are recommended during the bloom period, and only with materials not hazardous to honeybees.

Fruit-tree leafroller

Fruit-tree leafroller occasionally requires treatment in minimally treated groves. Pest control advisers working in Tulare County believe that the current University recommended treatment level (60 larvae per hour search) is much too low; but it is a good guideline for growers who are apt to overlook many of the well-camouflaged larvae.

Fruit-tree leafroller, like cutworms and katydids, is usually controlled in the spring spray program of typically treated groves. Control recommendations in minimally treated groves are similar to those for cutworms. Observations indicate that the biotic insecticide (*Bacillus thuringiensis*) effectively reduces fruit-tree leafroller populations. Unfortunately, this highly selective insecticide is less effective against cutworms.

Aphids

Many Tulare County citrus growers view aphids as pests; some believe that heavy populations cause bumpy fruit. Little, if any, data is available to substantiate aphid-produced economic

injury. In general, a parasite, *Lysiphlebus* sp. coccinellid predators, and syrphid predators, effectively control aphids. In years of prolonged, cool spring weather, natural enemies are less effective and high populations of aphids may persist until warmer weather. Aphids might be considered somewhat beneficial, because their honeydew acts as a nutrient for green lacewing adults and predaceous mites. Aphids are controlled in the spring spray program in typically treated groves. They are seldom treated in minimally treated groves.

Citricola scale

Citricola scale rates much higher in minimally treated groves than in typically treated groves for the same reason cutworms and katydids rate higher. In minimally treated groves, citricola scale eventually becomes a serious pest because its parasites are ineffective. Unlike brown soft scale, citricola scale has a single generation each year and the immature stages of the scale which are susceptible to *Metaphycus luteolus* are absent for long periods.

Fortunately, citricola scale is fairly easy to control with parathion. A well applied treatment often gives two years of control, sometimes three. It is important that these treatments be directed against low densities. High densities of citricola scale are difficult to control.

Supervised pest management

Because good citrus pest management requires considerable time, effort, training and experience, some growers have contracted the services of consulting entomologists. In this arrangement, the grower and entomologist should maintain close cooperation. Certain farm practices must be coordinated with important aspects of pest management. For example, some growers have apparently reduced their thrips problem by planting cover crops. Good irrigation management must be practiced if spray oils are to be used safely in Tulare County. Good chemical control depends upon the proper maintenance and use of spray equipment. Finally, since the grower is ultimately responsible for the risks taken, he must work closely with the entomologist to insure that good economic judgments are made.

The entomologist's responsibilities rest mainly with the technical development of pest management programs. Because of his training, he is equipped to develop programs for the continuous evaluation of pest potentials. He not only has to assess the immediate problem, but the long

range ones as well. How many times have growers sprayed the primary pest, only to get into trouble later with secondary pests? In anticipation of such problems, the entomologist considers the entire pest complex in control programs.

The supervising entomologist must also maintain a sound chemical program. Skilled pest management depends upon available chemicals that are highly effective. Nothing disconcerts pest management experts more than to watch resistance to perfectly good pesticides develop because of misuse or overuse. Resistant populations mean poor control, and additional repeated treatments result in selection for greater resistance. By using natural controls to minimize the use of pesticides, the entomologist prolongs the efficiency and life of chemicals.

Case history

For three years the writers supervised minimal treatment programs in a number of groves as part of a research and education program for citrus growers. In each grove we attempted to reduce pest control costs while maintaining the fruit quality to which the grower was accustomed.

No preventive treatments were applied in these groves. All treatments were recommended on the basis of population levels. University guidelines were used for worm treatments. Thrips treatments were recommended when 20% of the outside fruit in the groves showed thrips activity. This economic level was developed and is used by commercial entomologists in Riverside and Tulare Counties. No thrips treatments were recommended after the fruit reached walnut size. Citrus red mite treatments were not recommended. Research had shown that healthy growing citrus trees in Tulare County tolerate high populations of citrus red mite. Moreover, under minimal treatment programs, citrus red mite populations usually remain fairly low.

Parathion and sabadilla were the basic materials used in the program. No unusual biological upsets were observed with these materials. Citrus red mite sometimes increases behind parathion treatments, but predaceous mites remain effective.

Table 2 reflects the pest problems and costs in minimally treated groves in which red scale is not a pest. Table 3 presents data comparing the packout in a minimally treated grove with the packinghouse average. It is noted that the fruit quality from the grove with a \$26.70 pest control bill compared favorably with

that from groves with a \$73.00 bill. The latter is the average cost in Tulare County for groves without red scale.

Table 2 also shows that worms created no problem in the Muller grove during the three-year period. Some of the other groves monitored had worm problems, but not every year. The Muller grove was the only one with a katydid problem. This insect is deceptive and does considerable damage to the fruit, if not controlled.

Red scale reached pest status in only one of the groves monitored. In the Muller grove it was found for the first time in 1972, but only on one tree. Spot treatments should effectively control it, at least for a few years. Eventually, the entire orchard may have to be treated—at substantially increased costs. Intensively trapping this grove with pheromones to detect the hot spots may help to maintain a low-cost, spot-treatment program. Parasite release programs may also reduce the need for treatments.

A very low citricola scale infestation was intercepted in the fall of 1972 in the Muller grove. A prebloom treatment with parathion was planned in 1973. Experience has shown that a March treatment results in excellent control of low densities of citricola scale, without really disrupting the natural enemies of other pests. Citricola scale should not be allowed to increase to high densities. Natural enemies of this scale are ineffective and high densities pose spray coverage and control problems.

This research showed that the achievement of a minimal treatment program can be difficult. Groves with histories of heavy treatments pose the most problems. For reasons not entirely understood, these groves usually present—among other insect and mite problems—explosive thrips populations.

To achieve a minimal program without experiencing thrips damage, it proved helpful not to withdraw from the contact insecticides abruptly. For example, it usually does not pay to switch entirely to bait programs the first year. Baits are just not effective where excessive thrips populations exist. Parathion provides a good transition insecticide, effectively controlling thrips at petal fall, without unnecessarily destroying natural enemies.

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