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James J. Stapleton, Charles G. Summers, Beth L. Teviotdale, Peter B. Goodell, Timothy S. Prather, Editors

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ARTICLES

MANAGING SAN JOSE SCALE WITH DORMANT OILS. *Walt Bentley, Dick Rice, Kevin Day, and Carlos Hernandez, UC Kearney Agricultural Center.*

Introduction

San Jose scale (SJS), *Quadraspidiotus perniciosus*, has been a serious pest problem for stone fruit growers in California since first being introduced to the state in 1870. Various insecticides have been used to manage SJS. These have ranged from calcium polysulfiide, whale oil, mineral oils, organophosphate insecticides, and, most recently, insect growth regulators. Many types of dormant oils, Supreme oils, and Superior oils have generally given adequate control although not consistently in all geographic areas. This is particularly true for late harvested fruits which necessitates the need for other insecticides. Additionally, where more broad spectrum insecticides have been used for SJS and other pests such as peach twig borer (*Anarsia lineatella*) and Oriental fruit moth (*Grapholitha molesta*), insecticide resistance has developed. Insecticide resistance has been documented in the San Joaquin Valley. Even with extremely effective insecticides such as pyriproxifen (Esteem®), resistance has occurred quite quickly. Further evaluation of Supreme and Superior oil was

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done in an attempt to determine the influence of scale density on control with these horticultural mineral oils and to evaluate the potential of oils as alternative insecticides in order to delay the development of resistance to the newly developed synthetic insect growth regulators.

Methods and Materials

Two separate trials were performed in 1999. Trial one was done to evaluate the potential for two types of oils (a Supreme oil and a summer oil, with less potential for phytotoxicity) in controlling SJS, for fruit harvested in July. A block of mixed Black Amber and Queen Rosa plums was treated with a 400 gallon mixture of either Volck Supreme Oil (8 gallons per acre), Orchex 692 Narrow Range Oil (8 gallons per acre), or left untreated. These treatments were replicated three times and applied to 64 tree plots on February 10, 1999. Application was made at 2 mph. Treatment effects were measured by randomly sampling 200 fruit from each plot, for each variety at harvest in July and evaluating San Jose Scale infestation.

The second trial was conducted on a mixed block of Royal Diamond and Rosemary plums. In February 1998 four insecticide treatments were applied to 30 tree plots. The trial was replicated 3 times. Materials used were Applaud 70W at1.5 lb. per acre, Esteem 2.9 EC at 0.1 lb. per acre, and Diazinon 50WP at 2.0 lb. per acre. Each of these materials was applied with a dilution of 6 gallons of Volck Supreme oil in 400 gallons of water per acre. The fourth treatment consisted of Volck Supreme applied alone, at the rate of 6 gallons per acre in 400 gallons of water. On February 10, 1999, the 1998 treated areas were divided in half and treated with either Volck Supreme oil (8 gallons per acre) or Orchex 692 Narrow Range oil (8 gallons per acre). This was applied in a mixture of 400 gallons of water per acre with a high volume, air carrier sprayer, driven at 2 mph.. A split plot design was used with the main treatments being the 1998 scale populations and the subplot treatments being the 1999 oil spray. The design allowed for 6 replications of the 1998 treatments and 12 replications of the 1999 oil treatments. An analysis of variance (400 plums per treatment) was performed based on the number of scale infested fruit.

In addition to the evaluation of scale infested fruit, male flight activity was monitored in three replicates of untreated plum trees (Black Amber and Queen Rosa) and the Volck treated trees in the same block. A single Trece® SJS sticky trap baited with the SJS pheromone cap (changed once monthly) was placed in each of the three replicates. Traps were checked weekly until July and every other week from then on.

In the second trial (late harvested Royal Diamond and Rosemary plums), three trees were selected near the central area of each plot and two branches were wrapped with double sided sticky tape, on May 1. These tapes were removed two to four times per month through November to track both the activity of the crawlers and to investigate treatment effects of the oil.

Results

Where oil was used, San Jose scale fruit infestation of the Black Amber (7/3 harvest) and Queen Rosa (7/7 harvest) was significantly ($P<0.05$ Fisher's Protected LSD) less when compared to the untreated check. For the Black Amber, fruit infestation averaged 1.25% where Volck Supreme oil was used, and 1.50% where Orchex 692 oil was used. Infestation in the untreated Black Amber trees averaged 10.75% (Table 1). In the case of the Queen Rosa cultivar, the Volck Supreme treatment averaged 4.91% infested fruit, the Orchex 692 averaged 4.83% infested fruit and the untreated check averaged 14% infested fruit (Table 1). There was no difference between oil treatments as measured by scale infestation of the fruit.

Table 2 presents the scale infestation at harvest in both 1998 and 1999 based on the main plot treatments (1998 insecticides). In 1998, fewer scale-infested fruit were found in the Applaud and Esteem treatments compared to the other treatments. The Diazinon treatment also resulted in significantly ($P<0.05$, Fisher's Protected LSD) fewer scale infested fruit than the oil control. There was a significant interaction ($P<0.05$, Fisher's Protected LSD) between the 1998 treatments and the 1999 treatments, as measured by fruit infestation in 1999. The oil applications performed best where the previous years scale infestation of fruit was lowest. The use of Applaud or Esteem in 1998 followed by oil in 1999 resulted in 3.45% and 3.95 % scale infested fruit at harvest respectively in 1999. The 1998 control/1999 oil treatment resulted in 6.25% scale infested fruit at harvest in 1999. This treatment was not significantly ($P>0.05$ Fisher's Protected LSD) different than any of the other treatments. The 1998 Diazinon/1999 oil treatment resulted in significantly ($P<0.05$ Fisher's Protected LSD) greater scale infested fruit at harvest than the 1998 Applaud/1999 oil and the 1998 Esteem/1999 oil treatments.

The subplot treatments were Volck Supreme oil and Orchex 692 oil applied in 1999. Table 3 presents San Jose scale infestation based on the 1999 oil treatments. The Volck Supreme oil treated plots resulted in 4.13% infested fruit and the Orchex 692 oil treated plots resulted in 6.38% infested fruit. Treatments were significantly different (P<0.05, Fisher's Protected LSD) from each other.

Crawler activity through the 1999 season is shown in Figure 1. There were no statistical difference between treatments, as measured in crawler abundance. Male flight was traced only in the untreated Black Amber and Queen Rosa planting. There was no significant difference (P<0.05 Fisher's Protected LSD) in numbers of males captured between these two treatments on any of the recording dates. There were approximately twice the number of male scale trapped in the untreated plots. Figure 2 shows the flight activity of males throughout the growing season. Unfortunately, traps were not checked weekly during this period, but remained out for two weeks and the development of the third and fourth flight of SJS is not discernible. It is of interest, the relative similarity in male abundance, between the two treatments, during the overwintering flight. During the second flight, abundance of males becomes slightly greater in the untreated plots.

Discussion

Plums harvested in July of 1999 and treated with either Volck Supreme oil or Orchex 692 oil were found to have acceptable levels of San Jose scale infestation. Given the parameters of treatment in 1999, these two refined horticultural oils could be used to manage SJS infestation and delay the use of other insecticides to which SJS is known to develop insecticide resistance.

The results of test two, where plums were harvested in August, also showed successful control of SJS where infestation was measured to be lowest in 1998. These lower infestations of SJS in 1998 were found in the Esteem and Applaud treated plots. Although greater SJS infestation was found in the 1998 Diazinon treated and Oil alone treated plots, it was still acceptable. Either of the refined mineral oils used in this trial could be used, given the parameters of the 1999 application, where San Jose scale abundance is low. Where scale abundance is high, as measured by the previous year's infestation, the use of mineral oils may not provide acceptable control.

The use of double-sided sticky tapes was not as consistent a measurement as was scale infestation. However the sticky-tapes did describe the trends of infestation based on the number of crawlers found on them.

Acknowledgements

The authors wish to thank the California Tree Fruit Agreement for their generous support of this project. We also wish to thank Mike Ansolabahere of Valent Corporation and Barbara Kuhlman of Exxon Corporation for their assistance and support.

Table 1. Influence of two dilute oil sprays (2/15/99) on San Jose scale infestation of two plum cultivars. (200 fruit).

Treatment	Rate/Acre	Black Amber (7/3)		Queen Rosa (7/7)	
		% Infested	# of SJS	% Infested	# of SJS
Untreated	---	10.75 b	16.00 b	14.00 b	29.17 b
Volck Supreme	8 gal/400	1.25 a	1.25 a	4.91 a	8.92 a
Orchex 692	8 gal/400	1.50 a	1.75 a	4.83 a	8.00 a

Numbers followed by same letters are not significantly (P>0.05) Fisher's protected LSD test)

Table 2. Average % infestation of San Jose Scale infestation on Royal Diamond and Rosemary plum (400 fruit combined sample per plot), August 1999.

1998 Treatment + 6 gal Volck	Average % infestation	
	1998	1999*
Applaud 70W, 1.5 lb.	1.80 a	3.45 a
Esteem 2.9EC, 0.1 lb.	10.00 a	3.95 a
Diazinon 50WP, 2.0	31.20 b	8.67 b
Control	44.15 c	6.2 ab

Numbers followed by same letters are not significantly (P>0.05) Fisher's protected LSD test)
* Either Volck Supreme (8 gal in 400 gal water per acre) or Orchex 592 (8 gal in 400 gal of water per acre) on Feb 10, 1999.

Table 3. Average % infestation of San Jose scale infestation on Royal Diamond and Rosemary plum (400 fruit combined sample per plot), August 1999.

1999 Oil treatment	Average % infestation
	1999
Volck Supreme, 8 gal.	4.9 a
Orchex 692, 8 gal	6.23 b

Numbers followed by same letters are not significantly (P>0.05) Fisher's protected LSD test)

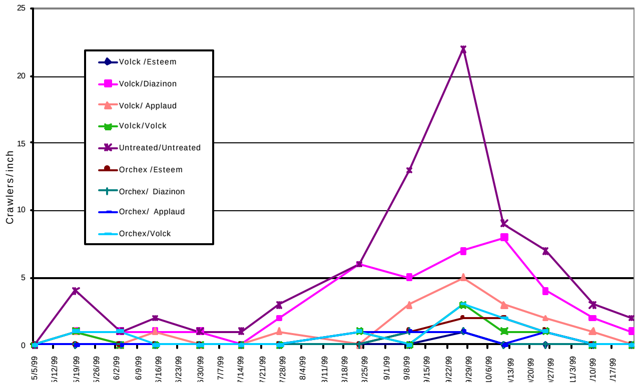

Figure 1. Seasonal San Jose scale abundance from plums exposed to different insecticide treatments1999/1998, KAC

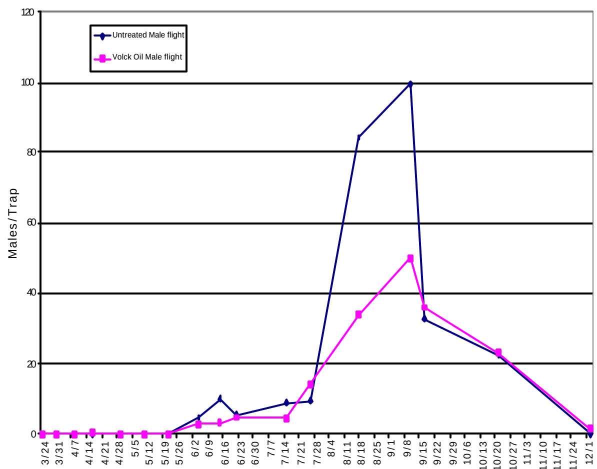

Figure 2. San Jose Scale Male Flight Activity, Plums, KAC, 1999

MANAGING LYGUS BUG (*LYGUS HESPERUS)* IN A REGIONAL CONTEXT

P.B. Goodell, S.D. Wright, and M.W.F. Carter, UC Kearney Agricultural Center, UCCE Tulare County, Agri-Consultants.

Abstract

The increasing portion of cotton production costs dedicated to insecticides is forcing a re-evaluation of managing Lygus bug (*Lygus hesperus*) in cotton in the San Joaquin Valley through mitigation of insect movement. The idea of managing crops around cotton to prevent the movement of insects into cotton is becoming more acceptable. The management of alfalfa hay is key to limiting the movement of Lygus into cotton and was suggested as a cultural management tool over 30 years ago. Using on-farm demonstrations, we confirmed the validity of this approach. We were able to limit the migration from alfalfa into cotton by two means. First, alfalfa harvests were staggered between fields to provide sufficient amount of suitable habitat. Second, uncut strips were left in harvested fields to maintain habitat during the period of harvest and regrowth..

Background

Lygus bug, *Lygus hesperus*, is the key pest in San Joaquin Valley (SJV) insect cotton pest management. Between 1990 and 1998, it caused average losses estimated at 60,279 bales of cotton annually (Williams, 1990-99). The degree of Lygus control that is required will set the stage for insect pest management for the entire year. The use of broad-spectrum insecticides for Lygus control upsets the balance of other pests such as aphids, spider mites, and foliage feeding worms.

Lygus is not an annual problem and its severity is linked to rainfall patterns and host availability (Goodell, 1998). Lygus moves from other hosts, including cultivated and uncultivated plants, in a manner described as aseasonal migration (Nechols et al, 1999). Aseasonal migration is movement from a host when it becomes unsuitable rather than a seasonal migratory event such as monarch butterflies. In the SJV of California, crop diversity provides many suitable sources for Lygus development including tomatoes, garlic, sugar beets, safflower, alfalfa, seed alfalfa and cotton. While not all of these crops are good hosts, associated weeds in the crop provide protective habitat or support reproduction. For example, in one typical 34 square mile area of the westside of Fresno County, 10 different crops could be found (Figure 1) with cotton and processing tomato dominating the landscape.

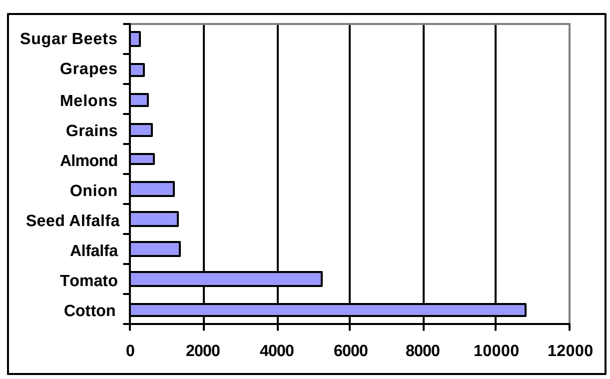

Figure 1. Crop diversity and number of acres of each crop in the westside of Fresno County in 34.68 square miles.

The migratory nature of Lygus offers challenges to the cotton industry that seeks to increase its biological reliance on IPM. During the growing season, it is not difficult to find cotton fields where pests are initially under biological control but within days of a migration of Lygus, require insecticide intervention to protect the yield. This rapid shift from a non-economically to economically-damaging level is unrelated to activities practiced internally within the field, but due to a migration external from the field. Dr. Vern Stern noted this problem over 30 years ago when he proposed managing the sources from which the Lygus originate in order to prevent cotton from becoming a sink for Lygus (Stern et al, 1967).

The application of broad-spectrum insecticides is the only control option once a population density exceeds the action threshold. This has resulted in secondary pest outbreaks and increased the proportion of production costs required for insect control. Over three decades ago, UC pest management guidelines recommended managing Lygus through habitat manipulation. These suggestions included management of Lygus in safflower based on heat accumulation (Sevacherian et al, 1977), developing alfalfa strips within cotton fields (Stern et al, 1969) and managing alfalfa hay through retention of uncut strips (Stern et al, 1967).

In 1998 and 1999, we conducted demonstration trials with alfalfa to manage Lygus movement into cotton.

Procedures

Strip Cutting Alfalfa, Tulare County, 1999. Steve Wright, Cotton Farm Advisor in Tulare County, was called to a farm at which Lygus bugs were consistently a problem. The farm was located near the St. John's River and contained both alfalfa hay and cotton (cv. NuCot 33B). Fields were ½ mile by ¼ mile and were 80 acres in size. The grower's practice was to harvest the alfalfa fields within days of each other without leaving any habitat in which Lygus could remain.

The demonstration trial consisted of three different cutting patterns in the alfalfa that was interspersed between cotton fields. During the June harvest, a variety of uncut strips about 15 ft wide were left in three alfalfa fields. One field retained only two outside strips, another retained two outside strips and one inside strip, and the third retained two outside strips and every irrigation "check". This corresponded to 1.8, 2.8 and 8 acres of alfalfa. Lygus densities were estimated weekly using a standard 38" sweep net in the alfalfa and the adjacent cotton during July 1999. A sample consisted of 50 sweeps across the cotton row or in a pendulum motion in the alfalfa.

Staggered Cutting of Alfalfa, Fresno County, 1998 and 1999. To improve management of Lygus on a large West Side farm, alfalfa harvest on 160-acre fields was staggered. This cutting schedule removed roughly one third of 900 acres of alfalfa on a weekly basis. Thus, two-thirds of the alfalfa was still available for Lygus, either ready to cut or receiving an irrigation after harvest. The alfalfa was sprinkler irrigated and 2-foot strips on either side of the hand-moved pipe were left uncut.

Population densities of Lygus were estimated with a standard sweep on a weekly basis in both alfalfa and surrounding cotton by Agri-Consultants as part of the regular pest management inspection service. Each sample consisted of 50 sweeps as described previously.

Results

These demonstrations reinforced the validity of earlier guidelines that managing alfalfa has value for managing Lygus in cotton. In the Tulare County trial in July, Lygus densities averaged 3 bugs per 50 sweeps in cotton compared to 108 bugs per 50 sweeps in alfalfa (Figure 2). The number of uncut strips remaining (2, 3 or 9) did not appear to be important in retaining Lygus in the alfalfa fields.

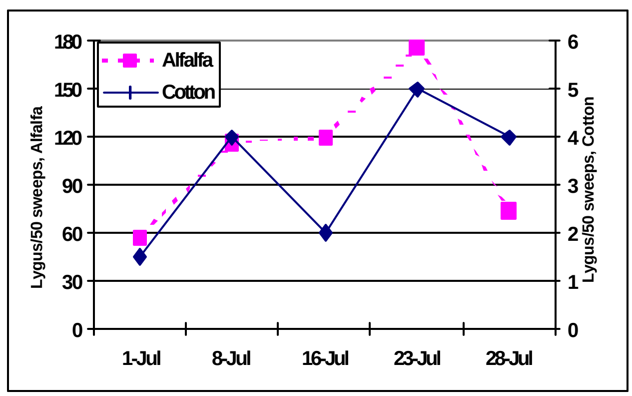

Figure 2. Lygus densities from adjacent alfalfa and cotton fields, Tulare Co. 1999

In the West Side Fresno County demonstration, the uncut strips within fields provided Lygus easy access to alfalfa habitat. More important, staggering the harvest of the 160-acre alfalfa fields created a mosaic of fields that provided ample habitat on the ranch to absorb Lygus movement from any field being harvested. This approach was successful in preventing Lygus migration into cotton during the two-year demonstration. In 1998, Lygus densities were higher in cotton fields located further away from alfalfa then in cotton located closer to alfalfa (Figure 3). Results were similar in 1999 (Figure 4), but Lygus densities overall were lower than 1998.

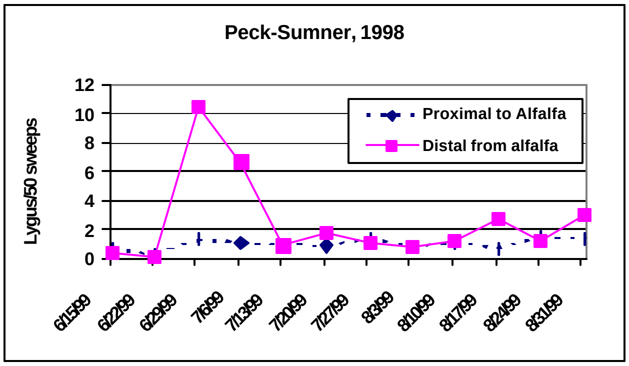

Figure 3. Lygus densities from cotton near alfalfa or distant from alfalfa, Fresno County 1998.

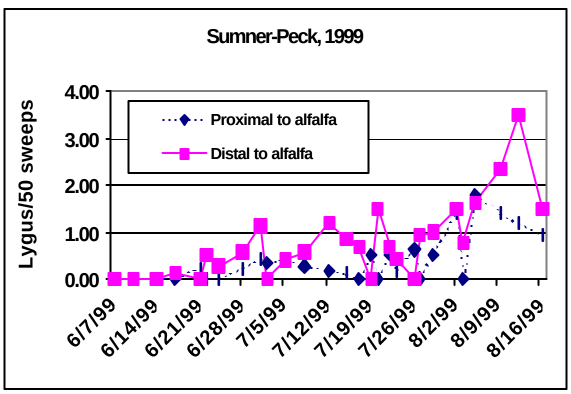

Figure 4. Lygus densities from cotton near alfalfa or distant from alfalfa, Fresno County 1999.

Discussion

As we move toward the 21st Century, IPM is being pushed to higher levels of systems management. The goal should be to move farming systems toward increased biological reliance and away from reliance on chemical intervention, with the result being increased biological and economic stability. In cotton production, the options for accomplishing this are limited. Lygus is a key pest for which:

- there are no products that have a narrow spectrum against Lygus or reduced-risk to human health,
- there are no commercially available biological control strategies,
- no host plant resistance has been identified from either traditional breeding efforts or genetic engineering.

Increasing cotton's reliance on more biological approaches to pest management will require strategies that manage Lygus outside of the cotton fields. Pest management of Lygus in the SJV should re-focus on managing the sources that encourage Lygus to remain and preventing migration of this pest. Prevention of Lygus problems in cotton is the key to decreasing our current reliance on chemical intervention. In cotton, moving toward more biological reliance will require the farmer, Pest Control Advisor, crop consultant, and Land Grant University to look well beyond the individual field and consider the surrounding landscape.

Alfalfa grown for forage can play a critical role in providing a continuously available habitat for Lygus population in a region. These field demonstrations reinforce the value of alfalfa in the cropping landscape proposed 30 years ago. Where possible, staggering cutting schedules of alfalfa in an area will do much to keep Lygus from moving into cotton, is easier to accomplish then strip cutting, and does not compromise the quality of the hay.

In areas that have a high proportion of land dedicated to alfalfa hay, scheduling alfalfa harvest to maintain Lygus habitat should be possible without directed coordination. In these situations, nearby alfalfa fields should be available to receive bugs forced out by the harvest process. Cooperation will be essential to the cotton grower who does not farm the alfalfa and his neighbor who does. The critical ratio of cotton to alfalfa remains to be elucidated.

As alfalfa becomes less dominant in a local ecosystem, block cutting within a field or preservation of uncut strips becomes more important. In block cutting, the field is divided and harvested at different times. However, block cutting and creation of uncut strips is much more intrusive in the normal management of alfalfa. There are concerns about the loss of revenue from uncut strips due to reduced value of the older hay to the diary industry. These concerns conflict with results of earlier trials (Summers, 1976) that found uncut strips when blended with newly cut hay, did not suffer a reduction in quality. This problem requires further study.

Alfalfa hay in the SJV provides our best hope of managing Lygus in a biologically intensive manner. In regions where alfalfa is found as a dominant plant cover, Lygus outbreaks are seen less frequently and with less severity. In areas with little or no alfalfa, cotton acts as a major sink due to the lack of other suitable hosts.

SJV cotton is similar to other cotton growing regions in the US where criticism has been levied for its over-dependence on insecticides. With a migratory pest like Lygus, the most direct way to increase biological reliance is to manage the ecosystem to eliminate its need for movement. Alfalfa can play a key role by providing alternative habitat to cotton, or in the future, acting as release site for biological control organisms against Lygus. Thus, the future strategy echoes the guidelines developed by an earlier generation of IPM entomologists, giving rise to the familiar refrain, *back to the future.*

Acknowledgments

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THRIPS CONTROL ON FRESH SHIPPING FRUIT

Richard Coviello, UCCE Fresno County, Walter Bentley and Richard E. Rice, UC Kearney Agricultural Center, and Kevin Day, UCCE Tulare County.

Introduction

The western flower thrips, *Frankliniella occidentalis* (Pergande), is a persistent and serious pest of smooth-skinned fresh shipping fruits, particularly plums and nectarines, grown in the San Joaquin Valley. Feeding damage reduces the marketability of the fruit. The most frequently used insecticides, formetanate hydrochloride (Carzol®) and methomyl (Lannate®) are beginning to lose effectiveness due to pesticide resistance. They likely contribute to the disruption of other pests such as San Jose scale and spider mites. They are also highly toxic pesticides which are under regulatory scrutiny because of worker safety concerns and, because of the Food Quality and Safety Protection Act (FQPA), may be withdrawn or severely restricted in the near future. A trial was conducted in 1999 at the Kearney Agricultural Center to evaluate alternative compounds, particularly reduced-risk materials, for efficacy in controlling western flower thrips.

Materials and Methods

Candidate materials for evaluation included: abamectin (Agri-Mek®), spinosad (Success®) and pyriproxyfen (Esteem®) compared with the standard Carzol and an untreated check. Esteem, which is not considered a thrips control insecticide, was included to develop information on performance against San Jose scale when applied at this timing. Treatments were applied shortly after petal fall on 25-Mar and 26-March. See Table 1 for chemicals and rates used in the trial.

Treatments were arranged in a randomized complete block design with six 3-tree replications across four varieties of nectarines. Treatments were applied by high-pressure handgun at approximately 225 GPA equivalent. Samples were taken from the middle tree in each replication. Treatments were evaluated by examining 100 fruit from each sample tree for thrips scarring at thinning and all harvested fruit at maturity. Fruit with any scarring that could be attributed to thrips feeding was counted as damaged. No attempt was made to measure the severity of scarring. The effect of the treatments on San Jose scale was evaluated by the use of double-sided sticky tape to sample scale crawlers and by examining the fruit for scale presence at harvest. In addition, scale parasitoids were counted on the tapes to ascertain the effects of the materials on non-target organisms.

Table 1. Chemicals used, rates / acre and application dates of treatments for thrips control evaluations at Kearney Agricultural Center in 1999.

Chemical	Product	Rate (lbs. ai/A)	Rate Product/A	Date Treated
abamectin	Agri-Mek 0.15 EC	0.01	10 oz.+oil	25-Mar
pyriproxifen	Esteem	0.09	12 oz.+oil	26-Mar
spinosad	Success 2F	0.09	6 oz. + oil	25-Mar
formetanate HCl	Carzol SP (92%)	1.38	1.5 lb.+oil	26-Mar
Untreated Control				

Results and Discussion

There were no significant differences among treatments for thrips scarring on fruit examined at thinning (Table 2). This may have been because the fruit was small at thinning and the small thrips scars were not as noticeable as they were later when the fruit increased in size. Because all thrips scarring was counted at harvest, including slight damage that would have been commercially packed, the percentages of damage on harvested fruit resulting from petal-fall thrips feeding were relatively high, ranging from 17.7% in the Agri-Mek treatments to 34.2% in the untreated check. All materials, including Esteem, reduced the percentage of petal-fall thrips scarring significantly below the untreated check (Table 2, Figure 1). There were no significant differences between materials. The fruit was also examined at harvest for pre-harvest "silvering" of fruit by thrips but no differences were observed among treatments (Table 2). This was expected since it was unlikely that any protective chemical residue would have remained on the fruit from the petal-fall application.

The effects of the treatments on fruit infestation by San Jose scale are shown in Table 2. Scale infestation was significantly reduced in the Esteem treatments when compared to Agri-Mek, Success and the untreated check but not less than Carzol. Agri-Mek, Success and Carzol were not significantly different from the untreated control. No significant differences were observed among treatments for the total numbers of scale crawlers caught on sticky tape throughout the sampling period. Numbers of parasitoids, such as *Encarsia* (*Prospaltella*) spp., caught on the double-sided tapes were too low to obtain any evaluation of the effects of the treatments on parasitoid populations.

Figure 1. Effect of treatments on the percentage of fruit with scarring resulting from thrips feeding at petal-fall. Columns with the same letter are not significantly different (DMRT, p= 0.05).

The results of this trial show two potential alternatives to Carzol for thrips control. Agri-Mek is not registered on stone fruits but should be in the near future. Success was recently registered on stone fruits with a 14-day pre-harvest interval on peaches nectarines and apricots, and 7 days on cherries, plums and prunes. Thrips are not listed as a target organism on the California label for stone fruits, but should be added this year. It remains to be seen if the 14 day preharvest interval on nectarines is close enough to harvest for this product to be useful to control the pre-harvest "silvering" damage from thrips. We plan to evaluate this aspect in 2000 in addition to validating our results from this year's trial. We also plan to evaluate other materials such as Trilogy®, cinnamaldehyde and garlic extract to control pre-harvest thrips damage.

Table 2. Effects of treatments on percent thrips scarring at thinning and harvest, and effects of treatments on percent of fruit infested with San Jose scale at harvest and total scale crawlers.

Treatment	% Fruit with "petal-fall" thrips scars: At Thinning	% Fruit with "petal-fall" thrips scars: At Harvest	% Fruit with "Silvering"	% Fruit with San Jose scale	Total No. SJS Crawlers
Agri-Mek	10.8a	17.7a	8.0a	18.3 b	666.9a
Esteem	16.7a	22.7a	15.0a	2.2a	103.8a
Success	11.1a	19.2a	16.7a	21.3 b	734.9a
Carzol	9.1a	21.7a	13.8a	11.8ab	570.1a
Untreated	13.9a	34.2 b	7.7a	23.7 b	479.2a
CV=	44.5	30.7	94.3	69.9	103.7

Numbers followed by the same letter(s) are not significantly different (DMRT, p=0.01).

BIOLOGY AND MANAGEMENT OF VERTICILLIUM WILT OF *PRUNUS* SPP. IN THE CENTRAL VALLEY OF CALIFORNIA

James J. Stapleton, UC Kearney Agricultural Center, and Roger A. Duncan, UCCE, Stanislaus Co.

Abstract. Verticillium wilt of *Prunus* spp. caused by *Verticillium dahliae*, sometimes known as 'black heart', is an occasionally serious disease problem in orchards in the central valley of California. Verticillium wilt is most severe on trees 2-6-years old, and symptoms lessen as trees mature. Usually only a few trees in a young orchard are affected, though sometimes many young trees die. Severe economic losses of $9,000-11,000 per ha resulting from Verticillium wilt in almond orchards have been recorded. Foliar symptoms may be difficult to discern after trees are 5-6-year-old. Unlike previous reports of new infections arising each year, recent research indicates that infections may survive in vascular tissue of primary scaffolds and trunks. Differences in tree damage are apparent among species and scion cultivars. Preplant fumigation with methyl bromide and/or chloropicrin is not consistently effective for prevention of Verticillium wilt. Solarization, with or without combination with methyl bromide can be used when applied prior to, or at planting, but post-plant therapeutic treatments with solarization are not advisable.

Biology. Verticillium wilt is a vascular wilt disease which affects many plant taxa, including *Prunus* spp. It is caused by the soil-inhabiting fungus *Verticillium dahliae*, which is widely distributed in California and other temperate regions of the world. Verticillium wilt of almond, sometimes known as 'black heart', was first observed in California nearly 100 years ago (Rudolph, 1931). The first proof of involvement of *Verticillium* spp. in the 'black heart' disorder of *Prunus* trees was provided in the 1920s (Czarnecki, 1923). In 1957, a list of susceptible host plants was compiled which included several economically important *Prunus* species (Englehard, 1957).

Unlike some other common perennial hosts such as olive and pistachio, only young *Prunus* trees are damaged by Verticillium wilt. Symptoms of Verticillium wilt in *Prunus* are similar in diverse growing regions of the world (Luisi et al., 1994), and include wilting (often on only one side of the tree), defoliation, death of scaffolds, shoots, and sometimes entire trees, and vascular discoloration. Foliar symptoms usually become visible during the first or second year of growth, may reappear for several consecutive years, and begin to disappear when trees are 4-6 years old. Trees may become stunted, asymmetrical, and produce poor yields. Almond (*P. dulcis*) and apricot (*P. armeniaca*) tend to be most affected of the commercial species. Scion cultivars within species also differ in susceptibility. In almond, for example, cv. Carmel is more susceptible than cv. Nonpareil (Asai & Stapleton, 1994; Stapleton & Asai, 1993). All peach and peach x almond hybrid rootstocks are highly susceptible; the plum rootstock Marianna 2624 (*P. cerasifera* x *P. munsoniana*) is somewhat resistant (Anon., 1985).

Colonization and plugging of xylem vessels by the fungus produces vascular discoloration of the tree trunk, branches, and twigs. Tree damage may occur even though foliar disease symptoms are not observable. Earlier reports indicated that infections in branches may die out each year, with reinfection occurring the next year through the roots (Anon., 1985; Ogawa & English, 1991). However, more recently the fungus was isolated year-around from above-ground tissues of infected trees (Stapleton & Asai, 1993) grown in the San Joaquin Valley (SJV). Another study employing destructive assay of second-leaf almond trees showed that while only 50% of trees showed foliar symptoms in an experimental orchard, 68 and 73% exhibited vascular discoloration in primary scaffolds and trunks, respectively (Stapleton et al., 1993) (Fig. 1). These data support the hypothesis that the fungus may survive in scaffold and trunk vascular tissue, as well as in roots (Stapleton, 1997).

Prunus orchards in the central valley are often planted on land on which susceptible crops or weeds previously grew, and in which populations of *V. dahliae* are established (Englehard, 1957). Numbers of *V. dahliae* propagules exceeding 60 per g of dry soil have been found in such soils; fewer than 5 per g are sufficient to cause a high incidence of Verticillium wilt in young almond and apricot trees (Stapleton et al., 1993). Isolates of *V. dahliae* recovered from diseased trees were found to include both defoliating and non-defoliating pathotypes of the pathogen when inoculated into cotton (Stapleton & DeVay, 1986; Stapleton et al., 1993).

Economic impact. A minor incidence of Verticillium wilt in a young *Prunus* orchard does not cause a significant economic impact. The main effect of the disease is to necessitate summer pruning to retrain trees in which major scaffolds have died. In severely infested orchards, however, establishment costs can be markedly increased by tree death and replanting costs, scaffold retraining, and production losses due to weakened trees. A 6-year study of two adjacent almond orchards in the SJV, both with a high incidence of Verticillium wilt, showed that cumulative tree mortality ranged from 23 to 50 trees per ha, with the grower incurring cumulative economic loss of $9,000-11,000 per ha (Asai & Stapleton, 1994).

Disease management. Once Verticillium wilt is evident in an orchard, proper irrigation and fertilization can help minimize economic loss, and summer pruning of dead branches may be necessary to develop proper tree shape (Anon., 1985). However, since therapeutic treatments are relatively ineffective and costly, prevention of Verticillium wilt is essential. Planting new orchards on land not previously farmed to wilt-susceptible crops or harboring susceptible weeds is a valuable strategy, when practicable. Thorough sampling of soil to determine population levels of *V. dahliae* is helpful to ascertain the level of risk prior to planting. Also, intercropping of susceptible crops in young Prunus orchards should be avoided. Although growers commonly fumigate soil with methyl bromide/chloropicrin mixtures prior to establishing orchards, results in California with respect to Verticillium wilt have not been consistently effective.

Solarization has been used experimentally as an effective soil treatment in California when applied prior to or at planting *Prunus* trees. One study in the SJV demonstrated that solarization beginning at planting and using transparent plastic mulch killed almond and apricot trees due to excessive heat, while similar treatment with black plastic mulch controlled Verticillium wilt without harming the trees (Stapleton et al., 1993). Use of solarization combined with soil drenching with metam sodium is sometimes used commercially for pre-plant treatment of sites where trees have died from Verticillium wilt. Post-plant solarization treatments which begin more than 2-3 weeks after tree establishment have not been consistently effective. This could be due to early infection of trees, followed by survival of the pathogen in above-ground scaffold or trunk vascular tissue. For effective use of both fumigation and solarization, thorough removal of old roots should be done prior to soil treatment.

In response to industry concerns regarding the impending loss of methyl bromide as a soil fumigant, a long-term (six year) field experiment was done during 1992-1997 to test effects of establishing apricot (cv. Patterson on apricot rootstock) trees with black polyethylene mulching at the West Side Research and Extension Center in the central SJV. The main objective of the trial was to evaluate and compare effects of the black mulch (solarization), alone and combined with a standard, 50:50 methyl bromide/chloropicrin soil fumigant mixture on development of Verticillium wilt. Because the use of in-season polyethylene mulches has not been well-studied in apricot (Duncan et al., 1992), effects of mulch treatments on several tree growth and physiological parameters were also determined. All soil treatments reduced numbers of *V. dahliae* propagules in soil. Although foliar symptoms of Verticillium wilt were not apparent during the course of the experiment, destructive sampling of the apricot trees showed vascular discoloration due to *V. dahliae* in 1.4-43.1% of scaffolds and 17.6-72.2% in trunks, as previously observed. Both solarization and fumigation treatments significantly reduced incidence of vascular discoloration of host tissue due to *V. dahliae*. Solarization and fumigation treatments increased flowering and fruit yields during the course of the experiment, and yields were inversely correlated to numbers of *V. dahliae* propagules in soil and to incidence of vascular discoloration. Other effects of the soil treatments included differences in tree vegetative growth, weed infestation, and conservation of irrigation water.

None of the pre-plant disinfestation treatments reduced numbers of *V. dahliae* in soil to undetectable levels over the duration of the experiment. Methyl bromide/chloropicrin fumigation of soil in 1991 initially reduced *V. dahliae* to undetectable levels, but the fungus had returned by 1995, presumably due to recolonization by surviving propagules. As reported previously, very few *V. dahliae* propagules were found deeper than 30 cm in soil. Also as in the previous study, evidence of infection by *V. dahliae* was readily apparent through vascular discoloration of excised scaffolds and trunks in destructively sampled trees. This lent support to our findings that annual appearance of foliar symptoms may not arise from new root infections each year, but rather from previously nonapparent infections surviving in trunk, scaffold, and/or root tissue. Also supported are results indicating that Verticillium wilt may reduce yields, even when symptoms are confined to scaffold, trunk, and/or root tissue, such that foliar symptoms are not observable. Black polyethylene film mulch was effective in controlling Verticillium wilt, increasing apricot fruit yields, and conserving soil moisture. The mulch, and to a lesser extent, fumigation treatments, were also effective for controlling weeds in the tree rows. Mulched trees were slightly more stressed than nonmulched trees, as indicated by leaf moisture potential readings, vegetative growth parameters, and possibly by increased flowering and fruit set responses. When the mulches were removed, indications of tree stress were no longer evident.

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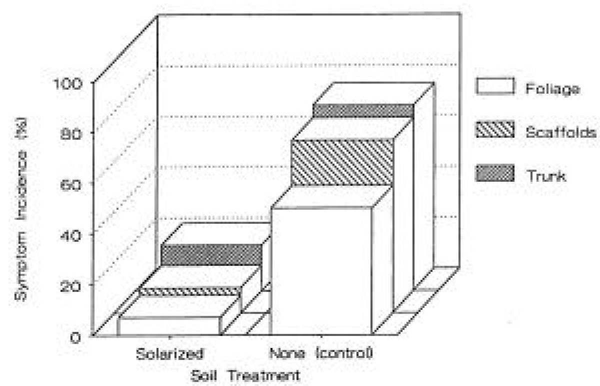

Figure 1. Influence of black polyethylene film mulching (solarization) on incidence of verticillium *wilt* -symptoms in foliage or vascular discoloration in scaffold or trunk tissue in second-leaf trees of almond cv. Carmel on peach cv. Nemaguard rootstock in the San Joaquin valley. Symptom incidence in each type of tree tissue was significantly different ($P < 0.05$) between solarized and control treatments. Adapted from Stapleton *et al. (1993).*