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

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POTASSIUM DEFICIENCY SYMPTOMS IN ACALA COTTON CULTIVARS CAUSED BY *VERTICILLIUM DAHLIAE*

J. E. DeVay, Plant Pathology Dept., UC Davis; B. L. Weir, UCCE Merced County; R. J. Wakeman, Plant Pathology Dept., UC Davis; and J. J. Stapleton, UC Kearney Agricultural Center.

Abstract

Potassium deficiency symptoms in cotton plants in California are widespread and often occur in plants grown in soil infested by *Verticillium dahliae.* The deficiency problem is mainly associated with cultivars of cotton (*Gossypium hirsutum*) that are susceptible to Verticillium wilt. Preplant soil solarization or fumigation with methyl bromide will eliminate the problem while the use of Verticillium wilt resistant cotton cultivars will greatly lessen its effect. Certain strains of *V. dahliae*, including those that have been isolated from cotton plants with potassium deficiency symptoms, will cause similar symptoms when injected into young healthy cotton plants; they also cause a significant decrease in the concentration of potassium in leaf petioles. These results suggest that infection of cotton plants by *V. dahliae* may cause an impairment in the uptake and translocation of potassium that is often associated with the development of potassium deficiency symptoms in cotton leaves.

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Leaves of cotton plants with Verticillium wilt develop interveinal chlorotic areas which eventually become necrotic. The chlorosis is due to the occlusion of leaf veins in limited areas of the leaves, cutting off the flow of sap to localized leaf tissues. The first appearance of the leaf symptoms, usually on lower leaves, results in a cessation of both plant growth and fruit development.

In contrast, less recognized symptoms caused by infection of plants by *V. dahliae* mimic potassium deficiency symptoms. Such symptoms may cause reductions in plant growth and lint yields, and first appear in younger leaves and begin with bronzing at leaf margins. The leaves develop a metallic sheen and become thick and brittle. Frequently, the leaf symptoms of potassium deficiency and the chlorosis and necrosis associated with Verticillium wilt may occur in single leaves.

The possibility that potassium deficiency symptoms in cotton in California may be associated with infection of plants by *V. dahliae* is suggested, by the following observations: (i) since the early 1960s, the selection of new cultivars of Acala cotton for resistance to Verticillium wilt has resulted in a simultaneous selection for resistance to the potassium deficiency problem; (ii) when highly susceptible cultivars (i.e. Acala SJ-2) are grown in fields where they develop potassium deficiency symptoms, foliar symptoms may be prevented by either soil solarization or fumigation with methyl bromide before planting and without additional fertilization with potassium; and (iii) potassium translocation is impaired in cotton plants infected by *V. dahliae.*

The objectives of this research were (i) to compare several isolates of *V. dahliae*, isolated from cotton plants with both potassium deficiency symptoms and symptoms of Verticillium wilt, for their ability to reproduce the symptoms in field-grown healthy plants; and (ii) to determine the effect of infection of cotton plants by *V. dahliae* on potassium levels in leaf petioles. The results of this study have been reported earlier (1).

Materials and Methods

Field tests. Leaf symptoms caused by *V. dahliae*. To evaluate isolates of *V. dahliae* for symptom induction, two cotton fields were chosen that had a history of the potassium deficiency problem. Sites were located in field areas of the Crivelli Ranch and the Santa Rita Ranch, both near Dos Palos in Merced County, that had been fumigated with methyl bromide at 628 kg/ha to eradicate populations of *V. dahliae* or other possible soilborne organisms that could contribute to the potassium deficiency problem. The cotton cultivar Acala SJ-2, which is susceptible to both Verticillium wilt and the potassium deficiency problem, was planted in raised beds in rows 100 cm apart. A randomized complete block design was used with four replications. In each block, each treatment row was 3.1 m in length. Ten plants in the mid-section of each treatment row were used for inoculations with *V. dahliae* or injections with sterile distilled water. Plants in the 10-11 node stage of growth were selected for treatment. The stem of each plant above the cotyledonary node was inoculated by injection at three sites with 10 µl amounts of conidial suspensions (10^6 conidia/ml) or injected with sterile water. The isolates of *V. dahliae* used included T-9, with black microsclerotial colonies on potato-dextrose agar (PDA), 1-k-1-3 and 2-k-1, both of which produced white colonies on PDA. Leaf symptoms began to appear approximately 2 weeks after inoculation and were recorded in mid-August during peak boll loads.

Field tests. Potassium content of leaf petioles. In tests to determine possible changes in potassium content of cotton plants infected with *V. dahliae*, studies were made at the San Juan Ranch and Bowles Ranch near Dos Palos in Merced County in cotton fields with little or no Verticillium wilt and where cotton plants had not shown potassium deficiency symptoms. The soil type at the San Juan Ranch was silty clay loam (29% sand, 50% silt, and 30% clay), slightly alkaline (pH 7.5) and with 110 ppm exchangeable potassium at approximately 15 cm soil depth. The soil type at the Bowles Ranch was clay loam (35% sand, 30% silt, and 35% clay), slightly alkaline (pH 7.6), and with 120 ppm exchangeable potassium at approximately 15 cm depth. Cotton cultivars used were Acala SJ-5, planted in 1993, and Acala SJ-2, planted in 1994 and 1995.

The experimental design and procedures for inoculation of plants with *V. dahliae* were similar to those used in the study of symptom development. The isolates of *V. dahliae* used in these field tests were T-9-1 and 1-K-1-1. Two types of inocula were used: in 1993 and 1995, freshly prepared conidial suspensions in water were used, whereas in 1994, a sand-corn meal mixture (95:5 vol/vol) was prepared which was placed in metal flats (34 cm wide by 46 cm long by 9 cm deep), moistened, and steam-sterilized twice in autoclavable bags at 121 C. for 4 hr. When cool, each flat was treated with 500 ml of spore suspension and incubated at 20 to 22 C for 6 weeks. Before use in the field, the contents of the flats were combined and thoroughly mixed for each isolate of *V. dahliae*. In 1993 to 1995, duplicate experimental tests were made each year to determine the potassium levels in cotton petioles. Each site consisted of a randomized complete block design with three treatments and four replications. Treatment rows, spaced approximately 100 cm apart, were 3.3 m long and contained about 50 plants. Inoculations with spore suspensions were done in 1993 and 1994 as previously described. The same treatments were used in 1994 with duplicate tests except only soilborne inoculum was used. Inoculum consisted of the sand:corn meal mixture infested with the isolates of *V. dahliae*. Three weeks after planting, the sand-corn meal mixture was buried about 15 cm deep on each side of the planting bed using 1000 cm^3/m of row. For the control treatment, the noninoculated mixture was used.

The data collected consisted of potassium analyses of petiole samples picked three times prior to and during periods of peak boll loads in July and August. Each sample consisted of 30 expanded leaves chosen at random from branches 6 to 7 nodes below the terminal node in each replication for each site.

Recovery of *V. dahliae* from inoculated plants. Stem or petiole samples from 5 plants from each replication were collected and placed in plastic bags and kept cool during storage. Subsamples approximately 1 cm long were rinsed under running tap water, surface sterilized, then plated on PDA. In field tests to compare the isolates for induction of foliar symptoms, final ratings and the collection of plant samples were made in August. However, in the field tests on potassium contents of petioles, collection of plant samples for the isolation of *V. dahliae* was delayed until after the final collection of leaf petioles for potassium analysis.

Data analysis. For each year, analysis of covariance was used to calculate the linear regression of petiole potassium on weeks after planting for each treatment and to test the homogeneity of the slopes. Additionally, two contrasts were done: (i) water control versus treatments, and (ii) 1-K-1-1 versus T-9-1. Linear regressions of petiole potassium levels over time also were done using the MSTAT-C program. Disease indices for potassium deficiency and Verticillium wilt symptoms caused by *V. dahliae* also were compared using the analysis of variance procedure in the MSTAT-C program.

Results

Foliar symptoms. Induction of foliar symptoms by isolates of *V. dahliae* was rated using a disease index for potassium deficiency symptoms and one for wilt symptoms (Table 1). The white isolates, 1-K-1-1 and 2-K-1, and the black microsclerotial isolate, T-9-1, all caused severe foliar symptoms of potassium deficiency and also the chlorosis and necrosis of leaves associated with Verticillium wilt, in contrast to the symptomless control plants. Some leaves of inoculated plants had both potassium deficiency and wilt symptoms, whereas other leaves had one or the other kind of symptoms.

Table 1. Development of potassium deficiency and wilt symptoms in leaves of cotton cultivar Acala SJ-2, stem-inoculated with *V. dahliae*.

Treatments	**Indices of foliar symptoms**	
	Potassium Deficiency[x]	Verticillium Wilt[y]
Field site 1		
Sterile water injection	1.5 a[z]	1.1 a[z]
Isolate 1-K-1-1 (white colony)	2.8 b	1.9 b
Isolate T-9-1 (black microsclerotial colony)	2.9 b	2.0 b
Field site 2		
Sterile water injection	1.3 a	1.0 a
Isolate 2-K-1 (white colony)	2.9 b	2.0 b
Isolate T-9-1 (black microsclerotial colony)	3.0 b	3.1 c

[x]Index for potassium deficiency was on a scale of 1 to 3: 1 = healthy; 2 = leaves bronzed with metallic sheen; and 3 = leaves as in 2 but thickened and brittle.
[y]Index for Verticillium wilt was on a scale of 1 to 4: 1 = healthy; 2 = often stunted plants with chlorotic areas in one or two leaves; 3 = extensive chlorosis and necrosis in two or more leaves; and 4, same as 3 but with defoliation.
[z]Values are means of four replications with 10 duplicates per replication. Means in columns followed by the same letter are not significantly different ($P > 0.05$).

Petiole analyses for potassium. Potassium levels in petiole samples for the different treatments were not significantly different in the first leaf collections. With increasing boll loads, however, and corresponding increases in demand for potassium in the developing bolls, plants inoculated with *V. dahliae* began to show a greater decrease in petiole potassium compared with control plants (Fig. 1). The slopes are given in Table 2. The probabilities for the test of homogeneity of slopes were not significant ($P > 0.05$), but the contrast for control versus treatments was significant ($P < 0.05$) for 1993 and 1994 (Table 2). There were no significant differences ($P > 0.05$) for 1995. The treatments with *V. dahliae*, in general, showed a more rapid decline in petiole potassium over time than did the control treatments.

Table 2. Treatment comparison of slopes from linear regression of petiole potassium on weeks after planting for each year.

Treatment	1993	1994	1995
1. Water control	0.050	0.368	0.400
2. Isolate 1-K-1-1	0.240	0.515	-0.561
3. Isolate T-9-1	0.227	0.622	0.575
Contrasts			
Control vs. Isolates	*[x]	*	NS[y]
1-K-1-1 vs. T-9-1	NS	NS	NS

[x]* = $P < 0.05$.
[y]NS = not significant.

Recovery of *V. dahliae* from test plants. Among the isolates of *V. dahliae* used, the black microsclerotial isolate, T-9-1, was recovered from all inoculated plants. In contrast, the white isolates which produce very few microsclerotia were difficult to recover, especially when plant samples were collected more than a month after the last soil irrigation. If collected within a week after soil irrigation, recovery was approximately 90% from the inoculated plants. Isolations from control plants injected with sterile water were all negative.

Discussion

The potassium deficiency problem in older Acala cotton cultivars, that became apparent in the early 1960s, has usually been considered due to a soil deficiency in potassium. However, while applications of high rates of potassium fertilizers to soils often increased lint yields, they seldom controlled or reduced the potassium deficiency symptoms in cotton leaves (2,3). The possibility that a soilborne microorganism might cause the cotton potassium deficiency is supported by the complete control of the problem resulting from soil solarization or soil fumigation with methyl bromide without potassium applications to soil (4). The impairment of potassium translocation in *Verticillium*-infected plants has been demonstrated (2), as well as the reduced incidence of Verticillium wilt by soil applications of potash fertilizer (2).

In the present study, the potassium levels in leaf petioles of plants inoculated with *V. dahliae* did not differ significantly from the noninoculated control plants until the plants were nearing a full boll load. This might be expected, since developing fruits are a strong sink for potassium. Linear regressions of petiole potassium on weeks after planting for isolates of *V. dahliae,* in general, showed a more rapid decline in petiole potassium than did the water control, with the contrast for the water control versus the fungal treatments being significant for 1993 and 1994.

The basis for the potassium deficiency problem in Acala cultivars of cotton in California has been controversial, but experimental evidence in the current work points to the involvement of *V. dahliae* as the causal agent.

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Literature Cited

1. DeVay, J. E., B. L. Weir, R. J. Wakeman, and J. J. Stapleton. 1997. Effects of *Verticillium dahliae* infection of cotton plants (*Gossypium hirsutum*) on potassium levels in leaf petioles. Plant Disease 81:1089-1092.

2. Hafez, A. A., P. R. Stout, and J. E. DeVay. 1975. Potassium uptake by cotton in relation to Verticillium wilt. Agron. J. 67:359-361.

3. Mikkelsen, D. S., B. L. Weir, A. Abshahi, and A. A. Hafez. 1988. Disease-induced potassium deficiency in cotton. Pages 514-515. In: Proc. 1988 Beltwide Cotton Research Conferences. J. M. Brown, ed. National Cotton Council of America. Memphis, TN.

4. Weir, B. L., R. H. Garber, J. J. Stapleton, R. Felix-Gastelum, R. J. Wakeman, and J. E. DeVay. 1989. Control of potassium deficiency syndrome in cotton by soil solarization. Calif. Agric. 43:26-28.

(Figure is unavailable)

Figure 1. Linear regressions of petiole potassium over time after planting showing the effect of *Verticillium dahliae* on the content of potassium in leaf petioles of cotton cultivars Acala SJ-2 and SJ-5. In 1993 and 1995, the plants were stem-inoculated with conidial suspensions of Isolates 1-K-1-1 and T-9-1 at the San Juan Ranch. Plants injected with sterile water served as a control treatment. The first data point in each regression is the time of stem inoculation or soil infestation with *V. dahliae*. At the time of the second data point, the plants were approaching a full boll load while the third data point is during the stage of full boll load and boll ripening. Data points in each regression are the means of four replications in each of two test sites each year.

USING ECOLOGICAL FACTORS TO DEVELOP REGIONAL MANAGEMENT APPROACHES FOR *LYGUS HESPERUS*

Peter B. Goodell, UC Kearney Agricultural Center.

Lygus bugs can be a major determinate in the profitability of a cotton season. The need for *Lygus* control, especially multiple applications of broad spectrum insecticides, can create the conditions for other insect and mite problems. Within the cotton production system, the costs of such insect control programs are getting out of the reach of most producers. Thus, if one can't afford to control *Lygus* once it has arrived in the field, what can be done to mitigate its arrival in the first place? This article will summarize the biology and ecology of *Lygus hesperus* in the San Joaquin Valley, point out important environmental factors in its buildup and migrations, and suggest regional approaches to mitigating its migration. These ideas are not original; they are built on the experience of previous entomologists over the past 30 years.

Lygus is an indigenous insect found throughout the West, well adapted to its environment, and with many natural enemies. *Lygus* is a pest of many crops in the San Joaquin Valley, including both fruit trees (apple, peach, nectarine) and row crops (cotton, edible beans, seed crops). *Lygus* has a wide host range of over 110 plants representing 24 families (Scott, 1977). Of the hosts listed by Scott, 70% are contained in eight families, Asteraceae, Fabaceae, Brassicaceae, Graminae, Chenopodiaceae, Plantaginaceae, and Rosaceae.

Rainfall and temperature are the critical environmental factors which determine the severity of an outbreak. *Lygus* overwinter as adults in alfalfa, orchards, and rangeland. Winter rainfall patterns set the stage for the abundance, diversity, and longevity of hosts. Early winter rains tend to favor production of grasses in the surrounding hills, which are not very good hosts for *Lygus*. Late winter rains favor broadleaf plants, such as filaree and clovers, which are suitable hosts for *Lygus*. Abundant rainfall in spring provides deep moisture for Russian thistle, extending growth of this host into mid-summer. In years when moisture is adequate to extend host plant growth into June or July, additional generations can develop resulting in large *Lygus* migrations into the Valley.

As the weeds dry and become unsuitable hosts, *Lygus* move into winter/spring crops including sugar beets, tomatoes, onions, garlic, and safflower. Depending on temperature, one or two generations can develop. As the crops mature, *Lygus* will migrate into cotton, seed alfalfa, or beans. The proximity of cotton, seed alfalfa, and beans to these sources contribute to the severity of the problem.

Cotton is not the favored host of *Lygus*, but the insects will migrate and settle there if no other hosts are available. In replicated, small plot trials at Kearney Agricultural Center, we found that lima beans were most favored, followed by cowpeas (blackeyes) and then cotton. Our data over two years showed that *Lygus* did not reproduce in cotton if beans were available. These bugs moved out of alfalfa into beans and did not return to alfalfa, suggesting a preference for beans over alfalfa.

From a cotton pest management perspective, there is much about *Lygus* biology we could use to our advantage. It is imperative that we begin to think beyond the field level in managing *Lygus* and look to the regional level in order to reduce its migration to cotton. It really is a matter of managing *Lygus* ***sources*** while providing ***sinks*** more preferred than cotton.

This approach is not new. Dr. Vern Stern understood the mobility of this pest and in 1967 promoted the idea of strip-cutting alfalfa in order to limit its migration from this crop. The increased acreage of alfalfa in the San Joaquin Valley makes this technique more important than ever. In areas with many alfalfa fields, staggered cuttings occur naturally. In areas with less alfalfa, especially with larger acreage fields, leaving a sufficient area uncut is important in preventing a large scale *Lygus* migration to cotton. However, staggering cuttings creates many problems for management and increases the cost of production since each field has to be handled almost as two. Summers (1976) suggested leaving alternate irrigation checks (berms, levees) uncut and found that *Lygus* remained in the uncut areas and recolonizied the main portion of the field within a week.

Stern (1969) also introduced alfalfa intercropping as a management strategy for *Lygus*. Intercropping was used for a few years in the late 1960's but fell out of favor because of the incompatibility of alfalfa and cotton production.

Our work indicates that cowpeas could serve as a buffer strip to attract and hold *Lygus* on the edge of fields. Field demonstrations in 1997 showed that cowpea can be planted with cotton and managed with the same irrigation regimes. The data indicated that *Lygus* did build in the buffer area to higher levels than in cotton, but cotton adjacent to the buffer did not suffer any increased damage. If populations require control, the strip and adjacent cotton are sprayed, not the entire field.

Sevacherian (1977) used *Lygus* phenology to time insecticide sprays in safflower before *Lygus* could migrate from safflower to cotton. This approach to treating the source (safflower) of *Lygus* rather than the sink (cotton) has been followed for 20 years. However, a limited choice of insecticides has reduced the usefulness of this approach. Sugarbeet is another crop that can host *Lygus*. Many weed species growing in sugarbeets are also excellent hosts. Tomato, onions, garlic, and fallowed ground can also develop weed communities which may support a population of *Lygus*. Care must be given to the management of these populations to avoid large-scale migration, rapid invasion, and excessive crop damage. Weedy sites need particular attention, since many of the hosts of *Lygus* act as invasive plants in disturbed areas. If left alone, these plants would be replaced with other less suitable *Lygus* hosts, such as perennial grasses. Plowing and discing fields provide the environment required for tumbleweed, lambsquarter, mustards, London rocket, and pigweed.

Managing *Lygus* in a regional context requires that producers have the willingness to work together, consider ideas which require cooperation and interaction, and plan strategically - not simply tactically. PCAs have traditionally played key roles in the management of *Lygus* during the season and developing tactics to manage it (sampling, decision making, resistance management). They have not been as actively involved in planning long term approaches (crop placement, influence of crop mix in an area, management of weed sources).

There are years when environmental conditions create severe problems and management may be difficult. In most years, however, developing a community plan to minimize *Lygus* migration into cotton could help. The following ideas are offered for consideration:

- Plant cotton away from known *Lygus* sources

- Place buffer strips of preferred hosts on the upwind border to slow migration. This strategy may not hold all *Lygus*, but should slow the migration and concentrate individuals into a “killing zone.” Restricting broad spectrum insecticide applications will preserve natural enemies in the larger portion of the field.

- Manage alfalfa in an area so there is an alternative habitat to cotton. This should be large enough to support the population in the cut area. Since the immature insects cannot leave the field, only space for adults is required. Dr. Summers’ suggestion of leaving alternate irrigation levees uncut is worth considering.

- Manage areas of known concentrations such as in safflower, sugarbeets, and weedy fallowed areas. If possible, treat high populations in such areas before plants becomes unsuitable hosts. Insecticide choice will be limited to products registered on the crop.

- Work with neighbors to manage understory plants in orchards. Mow frequently during April and May to prevent population maturation and migration.

- In the future, biological control may be used in areas serving as *Lygus* sources to reduce the general population in an area.

Developing regional management requires an understanding of *Lygus* biology and ecology in order to exploit weaknesses in the life cycle to our advantage. More important, it requires producers in an area to accept this approach as the most cost-effective, long-term approach to managing this mobile insect.

Literature Cited

1. Scott, D. R. 1977. An annotated list of host plants for *L. hesperus* Knight. Bulletin of the Entomological Society of America 23:19-22.

2. Sevacherian, V., V. M. Stern, and A. J. Mueller. 1977. Heat accumulation for timing *Lygus* control measures in a safflower-cotton complex. J. Econ. Entomol. 70: 399-402.

3. Stern, V. M. 1969. Interplanting alfalfa in cotton to control *Lygus* and other insect pests. Proc. Tall Timbers Conf. on Ecol. Animal Control. Number I.

4. Stern, V. M., R. van den Bosch, T. F. Leigh, O. D. McCutcheon, W. R. Sallee, C. E. Houston, M. J. Garber. 1967. *Lygus* Control by Strip Cutting Alfalfa. UC Agricultural Extension Service, Bulletin AXT-241. 13 pp.
5. Summers, C.G. 1976. Population fluctuations of selected arthropods in alfalfa: Influence of two

harvesting practices. Environmental Entomology 5(1):103-110.

USING SOLARIZATION TO DISINFEST NURSERY SOIL FOR CONTAINERIZED PRODUCTION

James Stapleton, Louise Ferguson, and Michael McKenry, UC Kearney Agricultural Center.

Abstract

Solarization was tested during summer 1995-1997 for its potential to disinfest nursery soils of certain nematode pathogens which attack perennial nursery crops in California's inland valleys. Moist field soils naturally infested with root-knot (*Meloidogyne incognita*), citrus (*Tylenchulus semipenetrans*), lesion (*Pratylenchus vulnus*), or ring (*Criconemella xenoplax*) nematodes were placed in black polyethylene (poly) planting sleeves or left in 30 cm high piles and subjected to one of four treatments for a period of one to four weeks: (1) placed on a sheet of black poly in the field and exposed daily to open sun; (2) as #1, but also covered with a single layer of transparent poly film; (3) as #1, but also covered with two layers of transparent poly separated by wire hoops; or (4) not heated. Soil temperatures reached as high as 48, 69, and 72 C in treatments 1, 2, and 3, respectively. Numbers of each of the test pathogens in soil or test plant roots were reduced by 89-100% by the various solarization techniques. Results of these experiments indicated that solarization may be used instead of chemical fumigation in containerized nursery operations in warm climatic areas.

Introduction

With the probability of losing methyl bromide as a soil disinfestant within the next few years, nursery operators need usable alternatives. Methyl bromide has been an important soil fumigant for containerized nursery production because of its excellent efficacy against a broad spectrum of soilborne pests. In most countries, stringent governmental regulations exist to prevent movement of soilborne pests on nursery material. For this reason, replacement treatments for nursery production must be capable of reducing soilborne pest populations to nondetectable levels. Soil solarization (3,6), a non-chemical, passive hydrothermal technique may be used for this application.

Producers of containerized transplanting stock in the San Joaquin Valley (SJV) of California currently use different methods for obtaining pest-free planting substrate. Some purchase "virgin" soil or organic media from off-site locations, while others use various methods of chemical soil disinfestation, primarily methyl bromide. Because of the high summer air temperatures in the SJV, the relatively small volumes of soil requiring disinfestation, and the positive results reported in several previous studies (1,2,4,5) solarization appeared to have excellent potential as a replacement treatment for use in nurseries. Therefore, solarization was tested during the summer months of 1995-97 for its potential to disinfest heavily-infested nursery soils of major nematode pathogens which attack perennial plants in California. Solarization treatments were tested in black plastic planting sleeves and soil in piles which was to be placed into sleeves after treatment. Soil infested with very high populations of pathogens was used to provide "worst case" situations. Commercial nurseries would not use such contaminated soil for producing containerized planting stock. A portion of this research has been summarized elsewhere (7).

Materials and Methods

One experiment was conducted at Kearney (central SJV) in 1995, using moist field soil naturally infested with the citrus nematode (*Tylenchulus semipenetrans*). Soil was placed in black polyethylene (poly) planting sleeves (20 x 45 cm) and subjected to one of four treatments for a period of four weeks: (1) placed on a sheet of black poly in the field and exposed daily to open sun; (2) as #1, but also covered with a single layer of transparent poly film; (3) as #1, but also covered with two layers of transparent poly separated by wire hoops; or (4) maintained in an incubator at 4 C.

A second experiment was conducted at a cooler site in the SJV near Oakdale (ca. 175 km north) during 1996, using soil mounds (914 cm x 914 cm x 23 cm) infested with the lesion nematode *Pratylenchus vulnus* and the ring nematode *Criconemella xenoplax* placed on black poly sheets. Two solarization methods were used - single tent, and double tent, using clear plastic film in both cases. Soil was mulched for a period of two weeks during July-August 1996. The control treatment consisted of mounds of soil not covered by plastic.

A third experiment was done at Kearney in 1997 to test effects of solarization treatments on the Southern root-knot nematode (*Meloidogyne incognita*). Experimental procedures were identical to those described for the 1995 Kearney experiment, except the treatment period was reduced to two weeks.

Numbers of test nematodes in soil were determined by sieve-mist (*M. incognita*, *T. semipenetrans* and *P. vulnus*) or sugar centrifugation (*C. xenoplax*) extraction, followed by microscopic evaluation. Extent of nematode colonization of olive or tomato roots was determined by mist extraction of nematodes.

Results and Discussion

In the 1995 Kearney experiment, soil temperatures in the center of the bags reached 48, 69, and 72 C in treatments 1, 2, and 3, respectively. Numbers of *T. semipenetrans* were reduced by 89-99% in sealed but untented bags, and the organisms were undetectable after treatment in either single- or double-tented bags.

In the Oakdale experiment, typical maximum temperatures at the bottom center of the soil mounds were 44 C in the single tent, 68 C in the double tent, and 36 C in the noncovered control. Each of the solarization treatments reduced *P. vulnus* to nearly undetectable levels by the end of the two-week treatment period.

Results of the 1997 Kearney experiment were very similar to those obtained in 1995, showing that a two week treatment period reduced *M. incognita* to undetectable levels in soil and test plant roots after single- or double-tent solarization treatments.

Destruction of the test pathogens in these experiments using heavily-infested soil indicated that solarization can provide commercial disinfestation of containerized nursery soils without the risk and expense of chemical or steam treatments. Solarization may be used commercially in nursery operations in the SJV and other areas with hot summer air temperatures.

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Literature Cited

1. Duff, J. D., and A. Barnaart. 1992. Solarisation controls soilborne fungal pathogens in nursery potting mixes. Australasian Plant Pathology 21(1):20-23.

2. Duff, J. D., and M. I. Connelly. 1993. Effect of solarisation using single and double layers of clear plastic mulch on *Pythium*, *Phytophthora* and *Sclerotium* species in a nursery potting mix. Australasian Plant Pathology 22(1):28-35.

3. Elmore, C. L., J. J. Stapleton, C. E. Bell, and J. E. DeVay. Soil solarization: A nonpesticidal method for controlling diseases, nematodes, and weeds. DANR Publication 21377, University of California, Oakland, 14 pages.

4. Kaewruang, K., K. Sivasithamparam, and G. E. Hardy. 1989. Effect of soil solarization with plastic bags on root rot of gerbera (*Gerbera jamesonii* L.). Plant Soil 120:303-306.

5. Patel, D. J., H. R. Patel, S. K. Patel, and M. G. Makwana. 1991. Soil solarization through clear polyethylene tarping for management of root-knot disease in a tobacco nursery. Tobacco Science 35:63-64.

6. Stapleton, J. J. 1997. Solarization: An implementable alternative for soil disinfestation. Biological and Cultural Tests for Control of Plant Diseases 12:1-6. APS Press, St. Paul.

7. Stapleton, J. J., and L. Ferguson. 1996. Solarization to disinfest soil for containerized plants in the inland valleys of California. Page 6 in: Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, Orlando, FL, November 4-6, 1996.

8. Stapleton, J. J., L. Ferguson, M. V. McKenry, D. S. Dougherty, and S. C. Stapleton. 1998. Using solarization to disinfest soil for olive nursery production. Acta Horticulturae: in press.

MANAGEMENT OF VEGETABLE INSECTS USING PLASTIC MULCH: 1997 SEASON REVIEW

C. G. Summers and J. J. Stapleton, UC Kearney Agricultural Center.

Introduction

Reflective mulches have been successfully used to reduce the incidence of aphid-borne virus diseases in vegetable crops (Brown et al. 1993, Summers et al., 1995) and evidence is mounting that they may be effective in managing whiteflies by delaying and reducing infestations. Edelstine et al. (1991) found reflective mulches effective in reducing the incidence of squash silverleaf in Israel. Schuster and Kring (1988) reported a reduction in *Bemisia tabaci* on tomatoes grown over reflective mulch. Csizinszky et al. (1997) found more *B. argentifolii* on tomatoes grown over white and black mulch than on those grown over orange, aluminum, or yellow. This is the third in a series of reports (Stapleton and Summers 1995; 1997) on reflective mulches and summarizes the results of our 1997 trials.

Materials and Methods

Treatments (mulches) were arranged in a randomized complete block design with 6 replicates. Mulches evaluated in 1 or more trials included: 1) silver embossed polyethylene AEP (AEP Industries); 2) Colorup® (Specialty Ag); 3) Brite'nup® HD [high density] (Sonoco); 4) Brite'nup® LD [low density] (Sonoco); 5) Polygon Yellow SLT® (Polyon);) bare soil control. The AEP and Polyon Silver plastics appear "gray" while Colorup and Brite'nup (metalized) cast the appearance of aluminum foil. Plants were grown on raised beds over which the plastics had been placed and anchored around the edges with soil. Plots were 3 rows wide by 7.6 m-long and separated from adjacent plots by 4.6-m of bare soil on all sides.

Results and Discussion

The incidence of aphid-borne virus diseases was low in 1997 providing us the opportunity to evaluate the effectiveness of the mulches for whitefly management. In pumpkins, all reflective mulches reduced the incidence of whitefly colonization and silverleaf syndrome (Table 1, 2). There was no difference in yield among the mulches and all out yielded the control (Table 3). Colorup was effective in reducing the density of corn stunt leafhopper, *Dalbulus maidis*, and the incidence of corn stunt disease (Table 4). Maximum yield was obtained in corn growing over the reflective mulch although yields over Polyon Red were higher than the control (Table 5). This is the first evidence that reflective mulches might be useful in managing leafhoppers. Additional studies are planned for 1998. All mulches worked equally well in reducing the incidence of alighting by adult whiteflies on cucumbers (Table 6). Fewer adults resulted in fewer nymphs (Table 7). Plants growing over all mulched produced significantly more fruit than did plants growing over bare soil (Table 8). While yields from plants g rowing over the Polyon Yellow were less than from those growing over reflective mulches, there were significantly higher than the control (Table 8). Reflective mulches significantly reduced the colonization of broccoli by silverleaf whitefly adults (Table 9) and plants growing over these mulches produced significantly higher yields than did those growing over bare soil (Table 10).

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Table 1. Mean no. silverleaf whitefly adults per leaf on pumpkins.

Sample No.	Mulch Type			Control
	Colorup	Brite'nup LD	AEP	
1	0.7a	0.8a	0.8a	2.1b
2	0.8a	1.1a	1.1a	5.3b
3	1.7a	1.8a	2.4a	20.2b
4	1.0a	1.7a	3.1a	9.9b

Means followed by the same letter(s) are not significantly different at P = 0.05. LSD.

Table 2. Incidence of squash silverleaf (SL) on pumpkins.

Sample No.	Mulch Type			Control
	Colorup	Brite'nup LD	AEP	
	% SL	% SL	% SL	% SL
1	0a	0a	0a	0a
2	0a	0a	0a	38.0b
3	<0.1a	<0.1a	18.0b	68.0c
4	13.0a	12.5a	44.4b	100.0c

Means followed by the same letter(s) are not significantly different at P = 0.05. LSD.

Table 3. Yield per plant of pumpkins and no. fruit per plant

Mulch Type	Mean Pounds of Fruit/Plant	Mean No. Fruit/Plant
Colorup	8.8a	1.3a
Brite'nup LD	8.5a	1.3a
AEP	7.0a	1.1a
Control	2.4b	0.6b

Means followed by the same letter(s) are not significantly different at P = 0.05. LSD.

Table 4. Mean number of corn stunt leafhopper per plot and the percentage of corn plants showing symptoms of corn stunt.

Mulch Type	No. Leafhoppers Per Plot	Percentage Corn Stunt
Colorup	76.0a	8.1a
AEP	239.8ab	18.2a
Red SLT	572.5b	55.6b
Control	475.8b	74.5b

Means followed by the same letter(s) are not significantly different at P = 0.05. LSD.

Table 5. Yield and stock length of corn grown over plastic mulches and bare soil.

Mulch Type	Pound of Ears/Plot	Stock Length (cm)
Colorup	36.6a	79.2a
AEP	34.0a	75.6ab
Red SLT	28.2b	73.9b
Control	16.3c	71.2b

Means followed by the same letter(s) are not significantly different at P = 0.05. LSD.

Table 6. Mean no. silverleaf whitefly adults per leaf on cucumbers.

Sample	Mulch Type					Control
	Colorup	Brite'nup LD	Silver SLT	Brite'nup HD	Yellow SLT	
1	1.5a	2.7a	2.9a	8.1a	10.9a	373.9b
2	8.5a	12.8a	34.0a	52.3a	67.3a	855.1b
3	11.1a	16.3a	30.8a	38.6a	68.0a	522.5b
4	18.1a	22.8a	39.2a	39.5a	88.1a	469.3b
5	17.4a	25.3a	30.4a	42.2a	133.6a	309.8b
6	12.6a	46.2a	46.6a	47.0a	48.7a	298.7b

Mean followed by the same letter(s) are not significantly different at P = 0.05. LSD.

Table 7. Mean no. silverleaf whitefly nymphs per leaf on cucumbers grown over plastic mulches and bare soil.

Sample	Mulch Type					Control
	Colorup	Brite'nup LD	Silver SLT	Brite'nup HD	Yellow SLT	
1	2.1a	2.9a	3.3a	4.6a	4.7a	34.4b
2	3.2a	3.5a	4.0a	7.7a	10.5a	49.6b
3	5.1a	6.9a	9.0a	10.4a	12.9a	107.5b
4	1.4a	3.0a	3.0a	5.1a	6.1a	38.9b

Means followed by the same letter(s) are not significantly different at P = 0.05. LSD.

Table 8. Cucumber yields, pounds per plot, for plants grown over and bare soil.

Mulch Type					Control
Colorup	Brite'nup LD	Silver SLT	Brite'nup HD	Yellow SLT	
60.6c	60.1c	53.9c	51.2c	38.3b	5.9a

Means followed by the same letter(s) are not significantly different at P = 0.05. LSD.

Table 9. Mean no. silverleaf whitefly adults per leaf on broccoli.

Sample No.	Brite'nup LD	AEP	Control
1	0.2a	0.3a	4.5b
2	0.3a	1.1a	2.7b
3	1.1a	1.3a	5.5b
4	0.5a	1.3a	2.8b
5	2.3a	5.9a	14.5b
6	2.4a	3.0ab	5.8b
7	2.9a	3.2a	4.3a

Means followed by the same letter(s) are not significantly different at P = 0.05. LSD.

Table 10. Yield, pounds per plot, of broccoli grown over reflective mulches and are soil.

Mulch Type		
Brite'nup LD	AEP	Control
29.5a	26.4a	12.3b

Means followed by the same letter(s) are not significantly different at P = 0.05. LSD.

Literature Cited

1. Brown, J. E., J. M. Dangler, F. M. Woods, M.C. Henshaw, W A. Griffy, and M. W. West. 1993. Delay in mosaic virus and aphid vector reductions in summer squash grown on reflective mulches. HortScience 28:895-896.

2. Csizinszky, A. A., D. J. Shuster, and J. B. Kring. 1997. Evaluation of color mulches and oil sprays for yield and for the control of silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, on tomatoes. Crop Prot. 16:475-481.

3. Edelstein, M., H. S. Paris, R. Shir, G. Beibowits, H. Nerson, and Y. Burger. 1991. Effects of reflective plastic mulch on fall-grown summer squash. Hassadeh 71:868-869.

4. Schuster, D. J., and J. B. Kring. 1988. Management of insects of tomato with UV-reflective mulches, pp. 5-19. *In* Report of tomato research 1987-88. Univ. of Florida, IFAS, Gainesville, FL.

5. Stapleton, J. J., and C. G. Summers. 1995. Reflective mulches repel aphids and protect cucurbitaceous crops from virus diseases. UC Plant Prot. Quart. 5(1):4-6.

6. Stapleton, J. J., and C. G. Summers. 1997. Reflective mulch for managing aphids, aphid-borne viruses, and silverleaf whitefly: 1996 season review. UC Plant Prot. Quart. 7(1):1-15.

7. Summers, C. G., J. J. Stapleton, A. S. Newton, R. A. Duncan, and D. Hart. 1995. Comparison of sprayable and film mulches in delaying the onset of aphid-transmitted virus diseases in zucchini squash. Plant Dis. 79:1126-1131.