Control of potassium deficiency syndrome in cotton by soil solarization

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Potassium-deficiency symptoms in cotton are widespread in California and become most apparent in leaves during heavy demand by developing bolls. Potassium fertilizers may reduce the problem, but the main cause may be pathogenic organisms in the soil. Soil solarization, which controls soilborne pathogens of cotton, also controls the potassium deficiency problem without appreciable changes in the availability of potassium to cotton roots.

A currently widespread problem in cotton, with symptoms resembling potassium deficiency, first became apparent in the early 1960s in Fresno and Tulare counties. The leaf symptoms of "potassium-deficiency syndrome" may appear as early as June, but usually become very obvious during July and August when demand for potassium is high. Leaf blades in the upper part of the plant become bronze in color with a metallic sheen; they thicken, become brittle, and are distorted along the margins.

Potassium-deficiency syndrome is now estimated to affect over 300,000 acres of cotton in the San Joaquin Valley and appears to be spreading in California. It has also been reported in Mississippi and South Africa, and was recognized in Israel in 1987. Earlier research has indicated that biological agents might incite the problem and that the symptoms are not always due to low potassium levels in the soil (*California Agriculture*, September-October 1982).

The high incidence of verticillium wilt in California cotton fields complicates the diagnosis, since cotton plants are often affected by both problems. In some fields where growers have attempted to control the potassium-deficiency problem by soil applications of potassium fertilizer, a reduction in the incidence of verticillium wilt has occurred. However, typical symptoms of verticillium wilt often develop in the absence of the potassium-deficiency problem.

In numerous field tests and greenhouse studies, University of California researchers have investigated the cause and control of the potassium-deficiency problem (*California Agriculture*, September-October issues of 1982 and 1986). Although increased lint production and a reduction of the symptoms resembling potassium deficiency have often been associated with potassium fertilization, the symptoms have seldom been eliminated. In contrast, soil fumigation with methyl bromide or combinations of 1,3-dichloropropene and chloropicrin, or the use of soil solarization, have not only increased yields but have also greatly reduced or eliminated the potassium-deficiency symptoms. We conducted soil solarization experiments from 1984 through 1987 in Merced County to learn more about the basis of the potassium-deficiency problem.

Experiments

Solarization. To solarize test plots in Merced County in the summers of 1984 and 1986, we laid clear polyethylene plastic sheeting (1.5 mil thickness) on fallowed fields. Areas covered with plastic were 150 feet long and 33 feet wide; they were replicated three times, with control plots of similar size between them for nonsolarized soil comparisons. All plots were irrigated by flooding under the plastic, and the plastic was left in place for 6 weeks during June and July of both 1984 and 1986. Soil temperatures were monitored at 6-, 12-, and 18-inch depths in both the solarized and nonsolarized plots. Within a week after the solarization treatment began, soil temperatures under plastic sheeting were approximately 10°C warmer than temperatures in nonsolarized soils. Average maximum temperatures in solarized soil were about 45°C (113°F) at the 6-inch depth, 41°C (106°F) at 12 inches, and 37°C (98°F) at 18 inches.

Soil preparation, weed control, and planting were the same in all test plots as in the

TABLE 1. Vascular discoloration in cotton stem tissue, associated with infection by *Verticillium dahliae* in solarized and nonsolarized field plots, Merced County

Cotton cultivar, treatment	Vascular discoloration* 1985	1987
	%	%
Acala SJ-2		
Solarized soil	40 a	5.3 a
Nonsolarized soil	100 b	92.3 b
Acala C-1		
Solarized soil	20 a	—
Nonsolarized soil	100 b	—
LSD at .05	49.7	2.2

* Values for 1985 are averages of 3 replications (100 plants/rep.); for 1987, 2 replications. Values followed by different letters within each year and cotton cultivar are significantly different at the .05 level.

TABLE 2. Effect of soil solarization on verticillium wilt, potassium-deficiency symptoms and lint yields of cotton, Merced County

Cotton cultivar/ location/soil treatment	Lint yelds*	Plants with leaf wilt and/or K-deficiency symptoms
	lb/acre	%
Acala SJ-2		
Sorg Ranch, 1985		
Solarized	997 a	< 10
Nonsolarized	619 b	100
San Juan Ranch, 1985		
Solarized	846 a	—
Nonsolarized	656 b	—
Sorg Ranch, 1987		
Solarized soil	874 a	< 2
Nonsolarized	664 a	100
Acala C-1		
San Juan Ranch, 1985		
Solarized	1,009 a	—
Nonsolarized	656 b	—
Sorg Ranch, 1985		
Solarized	998 a	< 10
Nonsolarized	994 a	100

* Values represent 33% turnout and are averages of 3 replications in 1985 and 2 replications in 1987. Values followed by different letters within each year and cotton cultivar are significantly different at the .05 level.

Acala SJ-2 cotton plants in nonsolarized soil (left) have thickened leaves with bronzed margins and a metallic sheen, typical symptoms of the potassium-deficiency problem. As co-author James DeVay demonstrates, the plants are stunted compared with the symptomless plants (right) growing in solarized soil. Both photographs were taken in mid-August at about the time of full boll set.

rest of the field. The soil in the experimental plots was left fallow until the following spring. In the 1984 experiment, each solarized and nonsolarized plot was planted in four-row patterns to both Acala SJ-2 and Acala C-1 cotton cultivars, which have moderate and high field tolerance to verticillium wilt, respectively. On May 15, 1985, the 1984 plot received three additional treatments: 250 pounds or 500 pounds of potash (K_2O) per acre, or 5 pounds of Topsin-M fungicide per acre. An untreated control was left for comparison. These materials were shanked into the shoulder of the bed about 4 inches deep and 4 inches to the side of the drill row. The 1986 experimental plots were similar to those in 1984 but only Acala SJ-2 was planted.

Soil samples. In 1986, we collected duplicate soil samples from solarized and nonsolarized plots following the solarization treatments in the two Merced County fields. For comparison with the Merced County soils (a history of verticillium wilt and the potassium-deficiency problem), soil samples were also collected from two solarized experimental plots at UC Davis. One of the Davis plots had been continuously in cotton for over 20 years with a high infestation of *Verticillium dahliae* Kleb. but without the potassium-deficiency problem. Soil was sampled with a horizontal probe at depths of 0 to 4, 4 to 8, 8 to 12, and 12 to 16 inches. Soil assays for exchangeable potassium and other mineral elements were done by the UC Cooperative Extension Soils Laboratory at Davis.

Leaf symptoms. In mid-August of the year following solarization treatments, we recorded the incidence of potassium-deficiency syndrome, leaf symptoms of verticillium wilt, and vascular discoloration in the cotton crop. (Vascular discoloration of stems is an early symptom of verticillium wilt that precedes foliar symptoms.) We sampled 100 randomly selected plants in each test plot in Merced County.

Results

In the 1984-85 experiment, there was a distinct difference between the solarized and nonsolarized plots in plant health of both cotton cultivars. By mid-August, potassium-deficiency symptoms were apparent in less than 10% of the plants grown in the solarized plots; the plants were taller, greener, and healthier than those in nonsolarized soil. In the nonsolarized plots, the incidence of the potassium-deficiency symptoms was 100% for both cultivars. Later in the season in the solarized plots, we noted reddening of leaves that appeared to be associated with the onset of plant senescence.

Results were similar in the 1986-87 experiments. Plants grown in solarized soil were wilt-free. And, at least until mid-August, they were again healthier, greener, and taller than plants in the nonsolarized plots, which showed severe potassium-deficiency symptoms.

Although less than 1% of the plants showed leaf symptoms of verticillium wilt in solarized plots, 5% to 40% were infected by *V. dahliae*, as indicated by vascular discoloration (table 1). In contrast, 100% and 92% of the plants in nonsolarized plots had vascular discoloration in 1985 and 1987, respectively.

Lint yields from Acala SJ-2 were significantly greater in solarized soil than in nonsolarized soil, except in the 1987 experiment where only two replications were harvested (table 2). Moreover, there was a much lower incidence of plants with potassium-deficiency symptoms and/or verticillium wilt in solarized than in nonsolarized soils. Lint yields of Acala C-1 in the San Juan plots were significantly greater in solarized soil than in nonsolarized soil. At the Sorg Ranch, however, solarization did not affect lint yields but caused a marked reduction in the incidence of the potassium-deficiency/verticillium wilt complex of symptoms. No significant differences in lint yields were found in 1985 at the Sorg Ranch for Acala SJ-2 or Acala C-1 when potash fertilization and Topsin-M treatments were compared in solarized and nonsolarized soils.

We compared the effects of soil solarization on potassium concentrations in different soils at various soil depths (table 3). Our purpose was to find out if solarization, which controlled verticillium wilt and greatly reduced or controlled the potassium-deficiency problem, would cause

TABLE 3. Influence of soil solarization on potassium concentrations in different soils and soil depths

Soil texture, source	Treatment	Exchangeable potassium by soil depths (inches)° 0-4	4-8	8-12	12-16	X
				ppm		
Clay loam,						
San Juan Ranch,	Solarized	143	143**	122	113	130*
Dos Palos	Nonsolarized	141	117	108	110	119
Loamy sand,						
Sorg Ranch,	Solarized	71	42	36	32	45
Dos Palos	Nonsolarized	68	55	47	43	53
Reiff silty clay loam,						
Armstrong Ranch,	Solarized	359	333	310	338	335
Davis	Nonsolarized	375	329	285	278	317
Yolo loam,						
Armstrong Ranch,	Solarized	261	195	189*	141*	197
Davis	Nonsolarized	275	184	124	105	172

NOTE: Soils were extracted with ammonium acetate solutions and analyzed by flame photometry by the UC Cooperative Extension Soils Laboratory, Davis.

° Values are averages of duplicate analyses; * and ** indicate statistically significant differences at each depth and each site comparison for solarized and nonsolarized treatments at P = 0.05 and P = 0.01, respectively.

marked changes in potassium availability. The Davis soils had high potassium levels, while the Dos Palos soils had adequate to marginal levels. Regardless of site or treatment, potassium concentrations tended to decrease with increasing soil depth. Average potassium concentrations were slightly higher in solarized soil than in nonsolarized soil at three of the four sites. These results are consistent with those from earlier studies, which showed that in most soils solarization has little or no effect on the availability of potassium. Soil solarization appears to increase the availability of mineral nutrients adsorbed to organic material, but has less influence on mineral nutrients like potassium, which are associated with clay particles.

Discussion

The evidence obtained in this study supports conclusions from earlier research that the potassium-deficiency problem in California cotton is not due to a lack of available potassium in the soil. In potassium-deficient soils, plants usually develop symptoms first in the lower leaves, but those with the "potassium-deficiency syndrome" first show symptoms in the upper leaves.

Removing the bolls will reduce or eliminate the symptoms, since developing bolls are a strong sink for potassium. It appears that a biological disease agent is causing a major interference in the translocation of needed potassium from roots and lower leaves to younger leaves and developing fruit. Treatments such as soil solarization, which would control a soilborne agent but would have little or no effect on potassium concentrations in soil, thus markedly reduce or eliminate the potassium-deficiency problem in the most severe field situations.

Soil solarization is a feasible control measure for the potassium-deficiency problem, since it also results in excellent control of verticillium wilt and weeds and often gives significant increases in lint yields. However, second-season observations indicate that it is more effective in the first than the second season. The failure of soil fertilization with large amounts of potash to effectively control the potassium-deficiency problem gives added incentive to identify the causal agent that is controlled by soil solarization or soil fumigation.

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Pistachio culls acceptable in livestock feed

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Whole cull pistachio nuts appear to be acceptable to cattle and sheep as part of their daily rations. Research indicates that cattle can be fed up to 20% of the daily ration without refusal, but this may be too high for sheep.

The pistachio industry in California annually produces an estimated 1.5% to 2.5% unmarketable in-shell nuts. These cull nuts are substandard because of insect damage, immaturity, undersize, or general poor quality. This study was designed to evaluate the use of these cull nuts as a livestock feed or supplement.

Pistachios are grown in 32 California counties, but the southern San Joaquin Valley counties of Kern, Tulare, Kings, Fresno, Madera, and Merced have over 93% of the total acreage in the state. In 1987, these counties yielded approximately 96% of the state's total production. Kern and Madera counties contributed 43% and 31%, respectively, of the total production in 1987.

Pistachio trees are alternate-bearing, producing a heavy crop one year followed by a light crop the next (table 1).

The nuts have a high fat content, especially the meats, but even in-shell nuts are high in fat (table 2). The estimated energy content of whole pistachios is also high (digestible energy = 3.72 Mcal/kg) because of the fat content. Protein is high in the meat but low in the whole nuts.

While nutrient analyses suggest that cull, whole pistachios could contribute to livestock rations, the question remains whether the shell-plus-meat cull nuts are acceptable to the animals. Excessive fat content could be a problem, since rations with as little as 20% nuts contain 6.4% fat, well over the suggested limit of 5% added fat (total ration dry matter) recommended by the National Research Council.

TABLE 1. California pistachio production

Year	Salable	Culls (estimated)
	tons	*tons*
1983	13,200	200 - 340
1984	31,000	470 - 795
1985	13,500	205 - 346
1986	37,450	570 - 960
1987	16,500	250 - 425
1988 (projected)	44,000	670 - 1,130

SOURCE: California Pistachio Industry Annual Report - Crop year 1987-88.