Disease-induced potassium deficiency and verticillium wilt in cotton

Lee J. Ashworth, Jr. □ Alan G. George □ Offa D. McCutcheon

New studies on the link to verticillium may help find the cause and ultimate control of the problem.

Healthy cotton field (above) and field affected by disease-induced K deficiency (below).

An unresolved potassium deficiency that involves entire fields when present sporadically affects 15 to 20 percent of San Joaquin Valley cotton fields. Its cause has been controversial for over 20 years. Two paradoxes are responsible for the controversy: first, cotton often suffers deficiency symptoms in fine-textured soils where other crops such as corn, alfalfa, sugarbeets, wheat, and sorghum grow well without potassium (K) treatments; second, the soils, by test, generally are not deficient.

In fact, 102 field tests on the influence of K on cotton yield in the San Joaquin Valley during 1951-66 showed that only coarse-textured soils such as Delhi loamy sand and Rippledon sandy loam were likely to respond positively to K fertilization; potassium enhanced yields in only 6 of 102 tests (Cotton Research Coordinating Committee Report, December 1966). However, K-deficient spots were known to occur in some fine-textured soils that suffered deep cuts during leveling.

Brown, Quick, and DeBoer confirmed these observations in greenhouse and laboratory experiments made with 94 soils. They related the amounts of K extractable with nitric acid and ammonium acetate with growth of corn in untreated and K-treated soil. Their tests (*California Agriculture*, June 1973) showed that a level of 200 ppm nitric acid extractable K correctly identified 97 percent of soils as being nondeficient for K. Although ammonium acetate results were less reliable than nitric acid results, extractable K values greater than 100 to 120 ppm suggested adequate levels of K in soils.

This type of potassium deficiency was first observed to be cotton variety-related in October 1966. Exceptionally severe deficiency symptoms (including defoliation) were observed in a cotton field near Tulare, which had 950 ppm nitric acid extractable potassium in the soil—four times the minimum level for K adequacy established by soil scientists. Severe deficiency symptoms occurred whether or not plants also suffered from verticillium wilt, as most did before harvest.

The cotton being grown was a breeder's seed line called 12302, which was released the following year (1967) as Acala SJ-1. Symptoms observed in the field of 12302 were much more severe than ever were observed in fields of Acala 4-42. Corn grown in this field the next year (1967) grew normally and produced well whether or not potassium was applied to soil, verifying its K sufficiency.

Cotton varieties that have succeeded Acala 4-42 and SJ-1 parallel one or the other of the old varieties with regard to their performance in problem soils. For instance, Acala SJ-2, which still commands about 80 percent of the San Joaquin Valley acreage, performs like Acala SJ-1, since it was selected from the same 12302 breeding material. Acala SJ-4 and Acala SJ-5 originated in breeding tests conducted in a problem soil of Tulare County, and they perform much like Acala 4-42 in such soils. Acala SJ-5 is genetically very similar to Acala SJ-4, since it is a selection made in the fifth generation instead of the fourth generation following the original cross of parent breeding lines.

Both cotton varieties currently grown in the San Joaquin Valley—Acala SJ-2 and SJ-4—suffer yield losses in problem soils, as determined by comparison of their yields in 14 fields free from the problem with yields in 12 fields where the problem occurred. Disregarding verticillium wilt, yields of Acala SJ-2 and SJ-4 were reduced in problem soils. Acala SJ-2 was reduced from an average of 1,185 pounds in nonproblem soils to 995 pounds in problem soils (16 percent), and Acala SJ-4 was reduced from an average of 1,229 to 1,145 pounds (7 percent). Acala SJ-4 outyielded Acala SJ-2 by an average of 13 percent (1,145 compared with 995 pounds) wherever the problem occurred. In absence of the problem, the two varieties yielded within 4 percent of each other.

Differences in ability of the cotton varieties to absorb potassium from the soil solution could account for these observations, even though the soils, by test, were not potassium-deficient. However, results of a greenhouse-laboratory test in sand culture watered with controlled amounts of K showed that Acala SJ-2 and SJ-4 were equally efficient potassium-absorbers, accumulating the same amount in a given length of time. Both varieties developed deficiency symptoms when the amount of K in petioles reached 0.2 ppm, whereas plants with 0.5 ppm petiole K grew as well as those with 4 ppm petiole K. Lint production by deficient plants (0.2 ppm petiole K) was reduced approximately 50 percent when compared with nondeficient plants, but, again, no differences between cotton varieties occurred. Therefore, other tests were made to determine whether K deficiency symptoms observed in affected fields were induced by disease.

Several tests in which soil was fumigated with a general biocide—a mixture of chloropicrin and methyl bromide—indicated that root disease might be responsible for the problem, because soil treatment blocked symptom development. However, cost of the treatment and other incidental problems precluded its use as a practical treatment.

Results of a grafting experiment at Waukena, California, in which the influence of roots on shoot growth was determined, also suggested that root disease could be responsible for inducing the potassium deficiency symptoms observed and accounted for differential responses of varieties. Seed of two strains of Acala 4-42 and of Acala SJ-1 were planted in closely spaced hills, and resulting plants were grafted together in all possible combinations. Later, roots and tops were appropriately cut off so that each variety grew on its own roots and also on the roots of the other varieties. Roots of Acala SJ-1 produced plants with reduced top weight (-25 to -33 percent) when compared with roots of Acala 4-42 (Model 58 and 66). Likewise, while still very young, roots of Acala SJ-1 plants were dark colored and reduced in amount, compared with those of Acala 4-42 plants.

Stachybotrys atra, a soil-borne fungus, was associated with affected roots and, in early tests, was about twice as common on Acala SJ-1 roots as on those of Acala 4-42. Pathogenicity of the fungus has not been established beyond doubt, however, nor is its

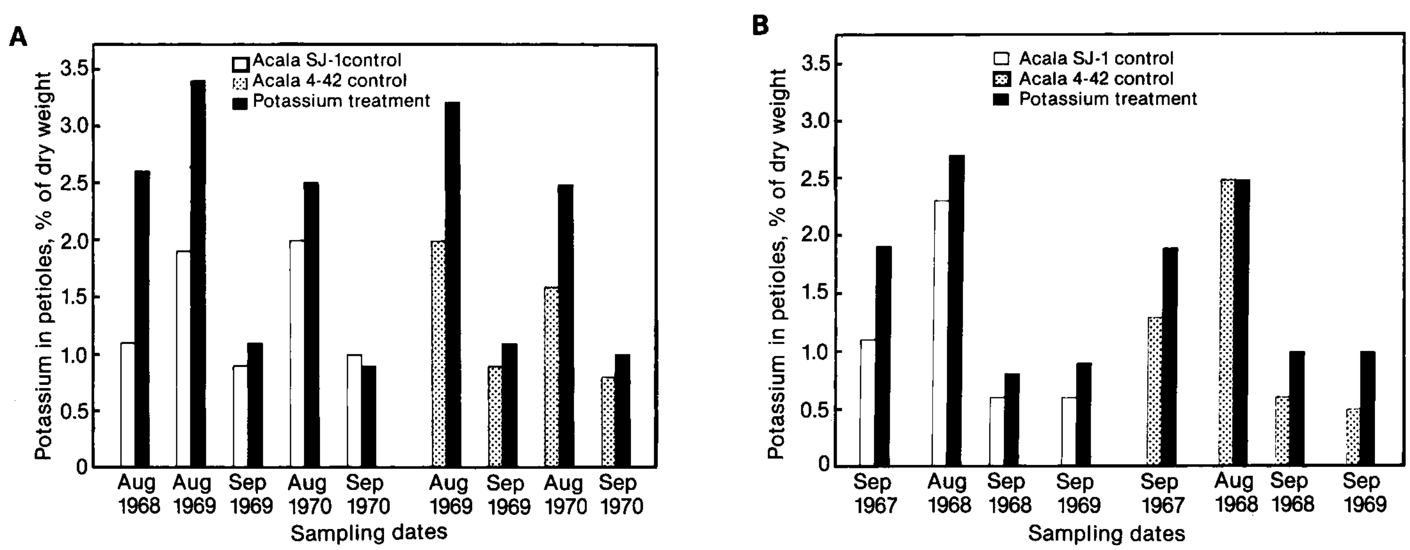

Fig. 1. Little difference in petiole K resulted from potassium treatments in Acala 4-42 or SJ-1 during September in either mild (A) or severe (B) verticillium wilt conditions, although moderate differences occurred in August under mild verticillium wilt.

relationship to newer cotton varieties known. Nevertheless, little doubt remains that the problem is induced, not by potassium-deficient soils, but by root disease that is more prevalent in some than in other cotton varieties.

Besides being more tolerant to the potassium problem, Acala SJ-4 and SJ-5 also are more tolerant than Acala SJ-2 to verticillium wilt, since they were selected in a Tulare County soil affected with both problems. However, Acala SJ-2 often outyields the other varieties at low to average inoculum densities (6 to 8 microsclerotia per gram of soil; *California Agriculture*, October 1980). This information on the influence of *Verticillium dahliae* inoculum density on disease severity and yield has made it possible to understand results of tests on the potassium problem made 10 or more years ago, when only one cotton variety was available, and we hope it will help define the cause and ultimate control of the problem.

Potassium deficiency of cotton in truly deficient soils is readily cured with 100 to 200 pounds K per acre, applied at planting. In these situations, an average fourfold difference in petiole K of plants in untreated versus treated soil was observed late in the growing season (September), and yields were improved an average of 20 percent in six tests. As pointed out earlier, however, fields such as these are rare and generally have coarse-textured soils.

Response to potassium by cotton affected with disease-induced deficiency is different. There, where 400 pounds of K per acre were applied each year, little difference in petiole K was observed in either Acala 4-42 or Acala SJ-1 during September in either mild or severe verticillium wilt conditions, although moderate differences occurred in August, under mild verticillium wilt (fig. 1). Late-season petiole K also was unaffected by K treatments in 35 other experiments, whether or not verticillium wilt was a problem.

Although petiole K content was not affected by K applications under these conditions, yields were improved under mild but not severe wilt, illustrating a connection between the root-disease-induced K deficiency problem and verticillium wilt. Tests were made during 1968-70 in a field near Waukena where verticillium wilt was not a problem: infection at harvest was never more than 15 to 30 percent (fig. 2A), which indicated that inoculum density (ID) of *V. dahliae* was about 1.5 microsclerotia per gram of soil. A foliage application of 20 pounds K per acre in 1968 was not effective (fig. 2B), nor was foliar application helpful in four out of five other tests (see table). But K application to soil at 400 pounds per acre was highly effective in 1969 and 1970, increasing yield by 26 to 38 percent

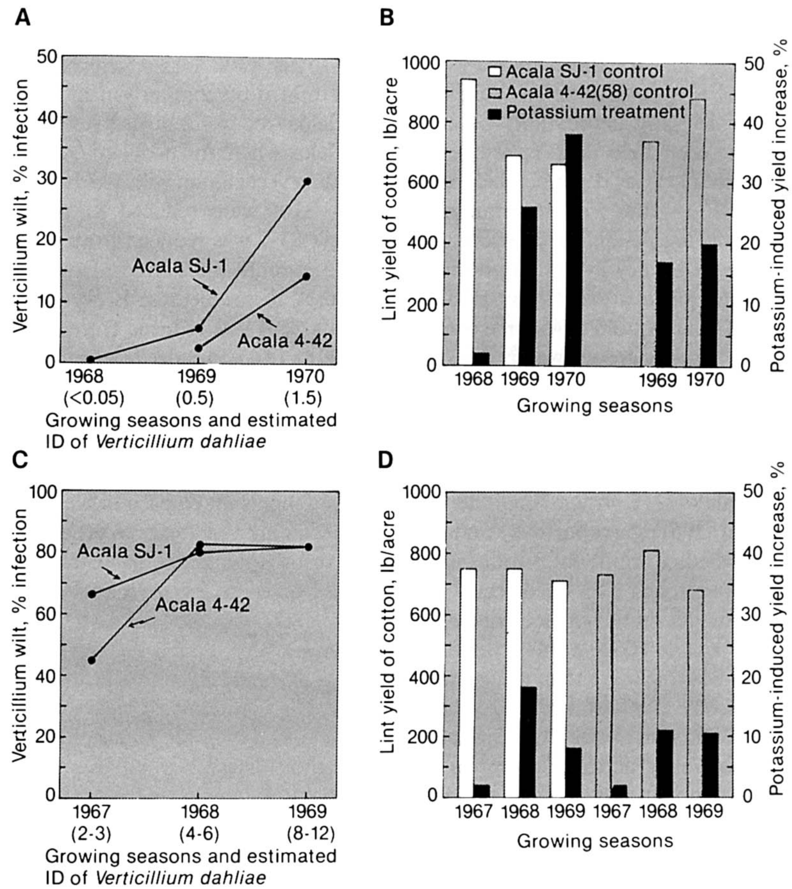

Fig. 2. Influence of potassium treatment on yields of cotton affected by disease-induced K deficiency. Yields improved under mild (A,B) but not severe verticillium wilt (C,D).

Influence of foliar potassium application on amount in leaf petioles during September and on yield.

Location	Soil type	Verticillium wilt	Soil K	Petiole potassium Untreated	Petiole potassium Treated*	Yield increase
		%	*ppm*	%	%	*lb/acre*
Tulare	Chino silty clay loam	100	155	1.9	2.0	None
Waukena	Chino clay loam	>90	137	0.8	1.0	None
Tulare	Traver loam	<1	88	0.6	1.0	None
Poplar	Hanford sandy loam	<1	66	0.4	0.6	None
Guernsey	Chino sandy loam	<1	56	—	—	120†

*20, 40, and 60 pounds per acre compared with no treatment.
†Average difference, untreated versus treated.

in Acala SJ-1, the most susceptible variety. The more tolerant Acala 4-42 benefited less than SJ-1 from K treatment—17 to 20 percent (fig. 2B). Application of potassium would have been profitable in this and nine other similar tests.

These observations contrast with those made at a field at Strathmore, where ID of *V. dahliae* was greater (fig. 2C, D). There, yield increases for K averaged only 8 to 10 percent for K treatments and would not repay the cost of potash. The results were typical of 25 other tests in fields having fine-textured soils.

Thus, while the cause of disease-induced potassium deficiency is not resolved, we know Acala SJ-5 will outyield Acala SJ-2 an average of 13 percent in affected soils, regardless of verticillium wilt. Current research focuses on determination of the causal agent, development of a laboratory test for identification of problem soils, and testing for tolerance to disease-induced potassium deficiency among new cotton varieties.

Lee J. Ashworth, Jr., is Plant Pathologist, Department of Plant Pathology, University of California, Berkeley, stationed at the San Joaquin Valley Agricultural Research and Extension Center, Parlier; Alan G. George is Cooperative Extension Farm Advisor, Tulare County, Visalia; and the late Offa D. McCutcheon was Farm Advisor, Kings County.