Growth retardants mitigate Verticillium wilt and increase yield of cotton

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Disease severity of Verticillium wilt was only slightly reduced by the nonfungitoxic compounds—but yield increased between 10 and 29 percent.

Verticillium wilt of cotton caused by *Verticillium dahliae* Kleb. can be only partially controlled by use of resistant cultivars. Because of the lack of a high level of resistance, other methods of control have been sought. Systemic fungicides, such as benomyl, were only partially effective and not economical. In our research on use of chemicals to control Verticillium wilt, growth retardant chemicals delayed the onset of symptoms, slightly mitigated the severity of symptoms, and reduced the internal population of *V. dahliae* in petioles. We report here the results of an extensive study of these nonfungitoxic, but biologically active, compounds in the field to determine their effect on the internal population of *V. dahliae* and on the yield of cotton seed and lint.

Materials and methods

The growth retardant chemicals were chlormequat (CCC) obtained as Cycocel from American Cyanamid—(2 chloroethyl) trimethylammonium chloride—Pix, from BASF, N,N-dimethylpiperidinium chloride (DPC), and tributyl [(5-chloro-2-thienyl)methyl] phosphonium chloride (TTMP)—Chemagro 8728 from Mobay—which has been withdrawn from commercial field testing.

All chemicals were water soluble, and dosages are given as the active ingredient. The wetting agent, Tween 20, was added to the aqueous solution of the chemicals to increase wetting of the leaves. The materials in solution were applied to cotton plants in some experiments at the initial square (flower bud) formation in late June and in others at early flower formation in early July. Application was made with back-pack sprayers. In most experiments, full coverage of both under and upper sides of leaves was made using 935 liters/ha. (100 gal/acre). In one experiment a lesser quantity, 187 liters/ha. (20 gal/acre), was compared with 935 liters/ha. Application was made in the morning when wind drift was minimal.

The Wilcox field in Tulare County had a long history of severe Verticillium wilt. The incidence of disease usually reached 75 to 100 percent each year. The field was rotated each year with milo. Plots were either one or two rows bordered by guard rows, laid out in a randomized block design with six replications.

Other experiments were done in field plots at the West Side Field Station of the University of California at Five Points, California, in which the incidence of Verticillium wilt was negligible.

In all experiments, plants in rows on beds 96.5 cm apart were thinned to about 9/m. On narrow rows (two rows were planted on each bed) the population was about 98,800 plants/ha. Cotton (cv. SJ-2) was planted except where designated otherwise; cv. SJ-3 and cv. SJ-4 were more tolerant to Verticillium wilt than cv. SJ-2.

A petiole was selected from an upper, fully-expanded but not senescent, leaf on at least 20 randomly-selected plants in each

replication. The petioles, refrigerated before isolation, were decontaminated, washed in sterile water, and blotted dry, and the ends were pared off and discarded. Small pieces were blended with sterile water, diluted, plated on a selective agar medium, and incubated at 21 and 24° C. After 8 to 12 days the microsclerotial colonies of *Verticillium dahliae* were counted on the plates and the number of propagules per gram of tissue was calculated.

Disease severity was estimated by evaluating between 20 and 50 plants in each replication for the approximate percentage of leaf area with foliar symptoms of Verticillium wilt. Disease severity was based on percentage of leaf area affected: 0 = healthy; 1 = 1 to 25 percent; 2 = 26 to 50 percent; 3 = 51 to 75 percent; and 4 = 76 to 100 percent. Disease incidence was based on the number of plants with foliar symptoms per number of plants evaluated.

Results

In general, the disease severity was only slightly reduced by the growth retardants. At 40, 80, and 160 g/ha., TTMP applied at initial square formation on June 21, at early flowering (July 15), and at both times, reduced the incidence and severity of disease only slightly. In a similar experiment, CCC at 10, 25, 50, and 75 g/ha. and TTMP at 40 g/ha. only slightly reduced either incidence or severity of disease. In 1975, TTMP (80 g/ha.), CCC (25 g/ha.), and DPC (25 g/ha.) had no effect on incidence of disease (approximately 100 percent), but the severity was significantly reduced by CCC in all experiments. Both DPC and TTMP reduced the severity in two experiments.

When samples of petioles from upper fully-expanded leaves were assayed, the population of *Verticillium dahliae* propagules was almost always reduced by the growth retardants. In one experiment, the internal population was reduced by TTMP (40 g/ha.) in the late season (September 5, 1974) as shown in fig. 1. Although earlier in the season there was a slight reduction in the internal population of *V. dahliae* by both CCC (10, 25, 50, and 75 g/ha.) and TTMP (40 g/ha.), the differences were not statistically significant.

The dosage of CCC on cotton was critical. The first dosage response experiment was conducted with CCC on the Wilcox farm, where Verticillium wilt was a factor. Yield of cv. SJ-2 was increased by CCC at 10 and 25 g/ha., with no significant effect at 50 g/ha. and 75 g/ha. The more resistant cv. SJ-3 had a response similar to cv. SJ-2, but the increase in yield was less. Yield of both varieties was increased by TTMP (40 g/ha.). In a subsequent experiment in 1975, CCC increased yield of SJ-2 at similar dosages.

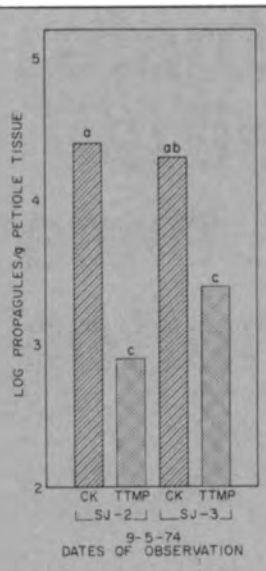
In another experiment at the West Side Field Station, where Verticillium wilt was not a factor, yield increases due to CCC at 10 and 25 g/ha. were also obtained. Higher dosages either were ineffective or reduced yield. Yield was increased significantly by TTMP (40 and 80 g/ha.).

The effects of growth-retardant application at squaring time (mid-June) and at flowering time (early July) were compared at different dosages. There was no effect due to time of application. At the lower dosage of 10 and 25 g/ha., CCC and DPC increased the yield significantly, but a dosage of 75 g/ha. of DPC decreased yield. In another similar experiment, CCC at 10 g/ha., DPC at 25 g/ha., and TTMP at 80 g/ha. significantly increased yield from 8 to 11 percent.

Increasing the dosage of TTMP applied at first squaring (mid-June), at early flowering (early July), and at both times did not affect yield in another experiment. The yield of cotton seed and lint was increased from 2644 kg/ha. to 2970 kg/ha. by TTMP (112 percent of control). Neither dosages nor time of application had any significant effect on yield.

In 1976 CCC and DPC were compared on cv. SJ-2, which is moderately susceptible to Verticillium wilt, and on cv. SJ-4, which is moderately resistant. Optimal dosages of chemicals increased yield on SJ-2 but not on SJ-4. The amount of water in which the chemicals were applied did not affect the yield. Since the differences on SJ-4 were not significant, only the data for SJ-2 compared to the control for SJ-4 are shown in fig. 2.

Dosages of TTMP at 40, 80, and 160 g/ha. did not affect plant height in field experiments in 1973, 1974, and 1975. Both CCC and DPC consistently reduced the height



*Letters a, b, and c indicate different statistical populations. (P = 0.01.)

Fig. 1. The effect of TTMP, applied at 80 g/ha. in mid-June to cotton foliage of two cultivars, on population of Verticillium dahliae in petiole tissue on September 5, 1974.*

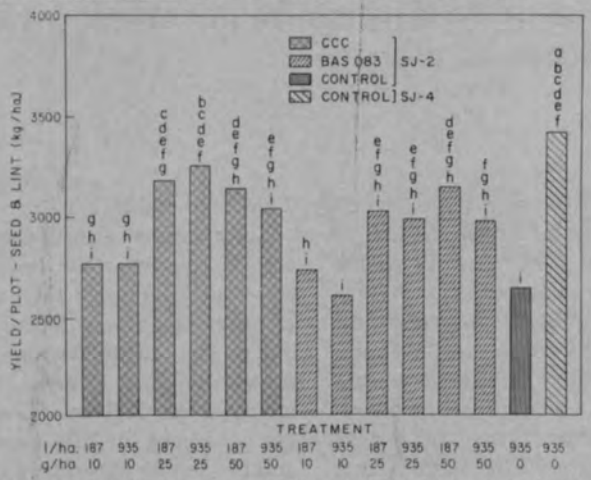


Fig. 2. Effect of CCC and DPC applied at early square formation (mid-June) on yield of cotton seed and lint on land infested with Verticillium dahliae.*

*The volume of solution used to spray the cotton is given in liters/ha. The dosage of each chemical is given in g/ha. The data for the effect of the growth retardants on cv. SJ-4 was omitted because differences in yield due to chemicals were not significant. Bars with the same letter do not differ significantly. (P = 0.05.)

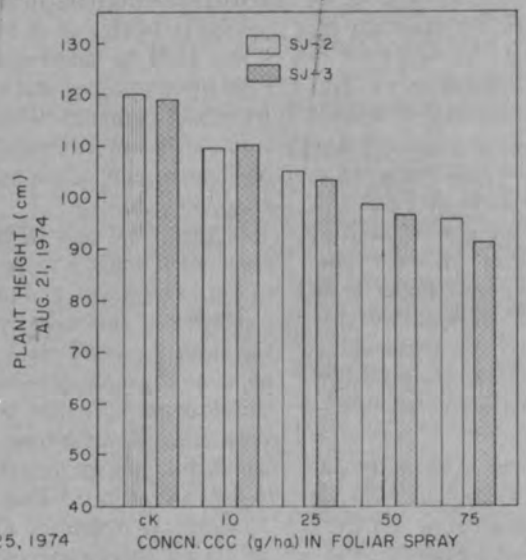


Fig. 3. Height reduction in two cultivars of cotton plants by application of CCC at different dosages.

linearly with increased dosage (see fig. 3).

There was a tendency for an increase in boll set with optimum dosage of growth retardants, but the differences were not statistically significant.

Discussion

The reason for the delay in onset of symptoms as a result of application of nonfungitoxic growth regulators is not yet understood. Furthermore, in much of the work to control disease with growth regulators, the side effects have been too serious for the control to be practicable. However, in results reported here, the lower dosages of 10 and 25 g/ha. actually increased the yield of cotton, slightly reduced the severity of symptoms and, perhaps more markedly pathologically, reduced the internal population of *V. dahliae* propagules in upper petioles. TTMP, DPC, and several other growth retardants also reduced the internal population of propagules in upper petioles.

The propagule-reducing effect of growth retardants was similar to that shown by resistant varieties in previous studies. The effect extended as much as 2 or 3 months after foliar treatment. It was tempting to conclude that growth retardants increased yield because of the suppression of *Verticillium dahliae* in xylem tissue (fig. 1). However, yield was also increased by growth retardants in a field in which Verticillium wilt was not an important factor. The reason CCC and DPC increase yield is not yet well understood.

Both CCC and DPC reduced height of plants. Since CCC reduces height by shortening internodes, the treated plant should have as much photosynthetic area as a nontreated plant. Reduction of cotton-plant height might be useful where rank growth and lodging of cotton is common.

It appears that the growth retardants tested in California might become practical if eventually registered for use because of the extremely small quantities of chemicals required. Because the concentration requirement for CCC and DPC was critical, dosage might be a problem under practical agricultural conditions.

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