Published July, 1964

Effects of Application Timing and Concentration of 2-Chloroethyl Trimethylammonium Chloride on Plant Size and Fruiting Responses of Cotton[1]

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INCREASING restrictions in cotton-acreage allotments have been accompanied by trends in production practices aimed at higher per-acre yields. These include a shift to the more fertile soils, the use of higher rates of nitrogen fertilization, and the use of more deep tillage and supplemental irrigation. All of these tend to increase yield potential by producing larger plants with more fruiting positions. However, if either poor insect control or inclement weather permits early loss of forms by shedding, the poorly fruited plants grow extremely tall, bear dense foliage, and tend to lodge. This rank condition is not only conducive to the rotting of bolls as they mature, but makes it difficult to obtain good chemical defoliation in preparation for mechanical harvesting.

A phase of cotton research that provides one approach to this problem centers on efforts to "tailor" the plant to a size that will facilitate defoliant application and mechanical harvesting. In field plots, various mechanical pruning treatments have been compared with foliar spray applications of an aqueous solution of 2-chloroethyl trimethylammonium chloride (CCC)[3] for preventing development of excessively large plants. Although there has been some reduction in yield from the use of the dwarfing chemical, the relative effects of application timing and concentration have not been clear-cut. The purpose of this report is to present results of a greenhouse experiment carried out to observe certain growth and fruiting responses of cotton treated with CCC.

REVIEW OF LITERATURE

The growth-regulating effects of CCC and related quaternary ammonium compounds have been tested on diverse plant species, many of which are ornamentals (1, 4, 8) but which also include wheat (6) and tomato (9). Application has been both by soil treatment and foliar spray, with the relative effectiveness of each method varying with plant species (8, 9). Treated plants characteristically produce dark-green foliage and develop short stem internodes; hence the term "dwarfing chemicals" has been applied to this class of growth regulators. Among the side-effects that have been noted are better keeping quality in chrysanthemums because of less wilting (4) and longer retention of green color in ripening wheat heads (6).

The effects of CCC and related compounds on flowering are varied. Cathey and Stuart (1) reported earlier flower-bud initiation of azalea, no effect on flowering of poinsettia, marigold, or zinnia, and delayed flowering of chrysanthemum. Wittwer and Tolbert (9) obtained 3-days' earlier flowering of tomato plants from CCC applied to the potting soil. However, maintaining given concentrations of the chemical in solution culture resulted in fewer flowers in the first cluster than on untreated plants. Tolbert (6) reported a delay of 2 to 4 days in heading out of wheat following treatment with CCC in greenhouse pot culture, although yield was not affected.

There has been little investigation of the effects of dwarfing chemicals on cotton. W. R. Cowley[4] compared CCC and several other growth regulators applied as foliar sprays to three varieties of cotton at the 6-leaf stage and at onset of flowering. In addition to retarding stem growth, both CCC and AMAB[5] resulted in some delay in maturity and reduction in yield, although boll weight and lint percent were unaffected.

MATERIALS AND METHODS

Cotton from a doubled haploid of 'Deltapine 14' (*Gossypium hirsutum*, L.), designated M 8948, was grown during the period from January to June in a greenhouse maintained at 24° C. minimum night temperature. Plants were cultured individually in 0.7 cubic foot of Bosket fine sandy loam in halves of 30-gallon drums. Bi-weekly applications of SPOONIT, a completely water-soluble fertilizer, were substituted for a normal watering. Basal vegetative branches were removed as soon as identifiable to restrict all growth and reproductivity to main stem and fruiting branches. Genetic material and cultural conditions provided adequate uniformity and permitted the plants to flower over a period of 6 weeks and attain a height of 5 to 6 feet at maturity.

Treatments included a control and foliar spray applications of CCC at 2 concentrations, 25 ppm. and 100 ppm., active ingredient, made at each of 3 stages of development: 2 weeks before flowering, at onset of flowering, and after 2 weeks of flowering. Spray applications were made to point of run-off. Each treatment was replicated on four plants.

Plant growth response was determined by measuring the length, in centimeters, of all internodes exceeding 1 cm. above the cotyledonary nodes on the main stem and on fruiting branches at maturity. Flower and fruiting responses were determined by tag-identification of flowers with date of anthesis and, subsequently, with date of boll dehiscence. Plant diagrams were made showing stem internode measurements and dates of flower and boll opening. Data from the diagrams were used in computing percent boll set, boll period (days from anthesis to dehiscence), and production of seed cotton, all by weeks of flowering.

RESULTS

Within 10 days after applications leaves of treated plants became very dark green compared to the more yellowish green of the rapidly growing control plants. Differences in stem elongation also became apparent after 2 weeks. These effects were least pronounced when the treatment was made after 2 weeks of flowering. Suppression of fruiting-branch elongation by the early application of the higher concentration was so pronounced that bolls at adjacent nodes almost touched each other. At no time were any of the treatments associated with severe shedding of squares or delay in flower opening.

A stepwise regulation of plant size was obtained by varying time of application and concentration, with the earliest treatment and the higher concentration producing the most suppression (Figures 1 and 2). Treatment at or before onset of flowering gave significant reductions in plant height compared with that of the control plants (Table 1). This reduction resulted from restrictions in length of main-stem internodes, in which the greatest number of internodes were affected by treatment before flower-

[1] In cooperation with the Delta Branch of the Mississippi Agricultural Experiment Station, Stoneville, Mississippi. Received for publication Feb. 17, 1964.

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[3] Presently designated CYCOCEL, obtained from American Cyanamid Company.

[4] Personal communication, 1960, of unpublished results.

[5] Allyltrimethylammonium bromide.

Figure 1. Effect of time of application of CCC on cotton plant growth. Concentration 25 ppm sprayed to run-off. (A1) 2 weeks prior to flowering, (A2) onset of flowering, (A3) 2 weeks after onset of flowering.

Figure 2. Effect of CCC concentration on cotton plant growth when applied at onset of flowering. (A2) 25 ppm, (B2) 100 ppm.

ing, and by the higher concentration in treatments made at onset of flowering. A similar time-concentration effect occurred on the internodes of fruiting branches.

Suppression of plant growth was accompanied by corresponding suppression of fruiting responses (Table 2 and Figure 3). Rates of flowering were significantly reduced in the fourth and fifth weeks by the preflowering treatments, and in the sixth week by treatments at onset of flowering. Preflowering treatments resulted in reduced boll set from the third through the fifth week of flowering, while beginning-flower treatments reduced set principally during the fourth and fifth weeks. Reduction in total matured bolls per plant by all preflowering and beginning-flower treatments was statistically significant at the 1% level of probability.

Seed cotton production per plant from each week of flowering (Figure 4) showed significant reductions which varied with CCC concentration as well as with time of treatment. With preflowering treatment (2A and 2B) there was significant reduction from the third and fourth

Table 1. Effect of CCC on final plant height and on length (cm.) of internodes of main stem and fruiting branches† of greenhouse-cultured cotton. Means of 4 replications.

Application		Plant ht.	Mean length of main stem internodes by groups				Branch length for indicated internodes		
Time‡	ppm.		1-3	4-7	8-11	12-15	1	2	3
A	25	92 bc	4	4**	6**	6**	11**	7**	6**
	100	82 c	4	3**	4**	5**	10**	6**	5**
B	25	106 b	5	6	7	4**	14	9**	7**
	100	94 bc	4	6	6**	3**	14	8**	6**
C	25	135 a	5	6	8	9	16	12	11
	100	126 a	5	6	8	8	16	12	11
Control		136 a	4	6	8	8	15	12	12

** Difference from corresponding control significant at the 1% level. a,b,c, Means in same column followed by the same letter are not significantly different at the 1% level. † First 10 branches only. ‡ A- 2 weeks before flowering, B -at onset of flowering, C - after 2 weeks of flowering.

Table 2. Effect of CCC treatments on flowering rate of cotton. Flowers per plant, by weeks.

Application		Week of flowering							Total flowers per plant
Time‡	ppm.	1	2	3	4	5	6	7	
A	25	4	6	8	10**	8**	4	2	42*
	100	4	6	8	12	10*	5	3	48*
B	25	5	7	11	13	12	3*	0	51*
	100	4	8	11	12	11	3*	2	51*
C	25	5	8	12	17	13	6	0	61
	100	4	8	11	16	15	8	0	62
Control		4	6	11	15	14	6	3	59

*,** Difference from control significant at 5% level and 1% level † A - 2 weeks before flowering, B - at onset of flowering, C - after 2 weeks of flowering

weeks with 25 ppm, and reduction from the second through the fifth week with 100 ppm. Likewise, in applications at onset of flowering (3A and 3B), 25 ppm affected production from the fourth week while 100 ppm affected production from the third, fourth, and fifth weeks. Slightly reduced production from either the fourth or the fifth week resulted when treatment was delayed until after 2 weeks of flowering (4A and 4B). Total seed cotton production per plant was reduced either 34 or 36% by preflowering applications and 18 or 22% by treatment with 25 ppm or 100 ppm, respectively, at onset of flowering. These reductions were significant at the 5% level. The growth and fruiting responses were closely interrelated (Table 3), indicating an association between plant size, as influenced by the growth retardant, and potential for fruit production.

Slight but statistically significant increases in boll period resulted from CCC treatments (Table 4). Data for untreated plants indicate slightly longer periods for bolls from the early weeks of flowering and shorter periods for later bolls. Preflowering treatments with CCC effected increases for most weeks of flowering and treatment at beginning flower showed increases over a shorter segment of the flowering period, while treatments after 2 weeks of flowering gave increases for the fifth and sixth week only.

DISCUSSION

Results from the greenhouse experiment have confirmed the more general observations from field plots that if CCC is applied early enough to cause material restriction of plant size there are side-effects that tend to reduce yield and may also cause some delay in maturity. Reduced rate of flowering was evident but of comparatively minor importance.

Table 3. Coefficients** of correlation between cotton growth and fruiting responses to treatment with CCC.

Plant response	Length of branches (cm.)	Total flowers	Total bolls	Seed cotton (g.)
Plant height (cm.)	.94	.88	.86	.84
Tot. length of branches (cm.)		.93	.89	.87
Total flowers			.90	.89
Total bolls				.94

** Significant at the 1% level.

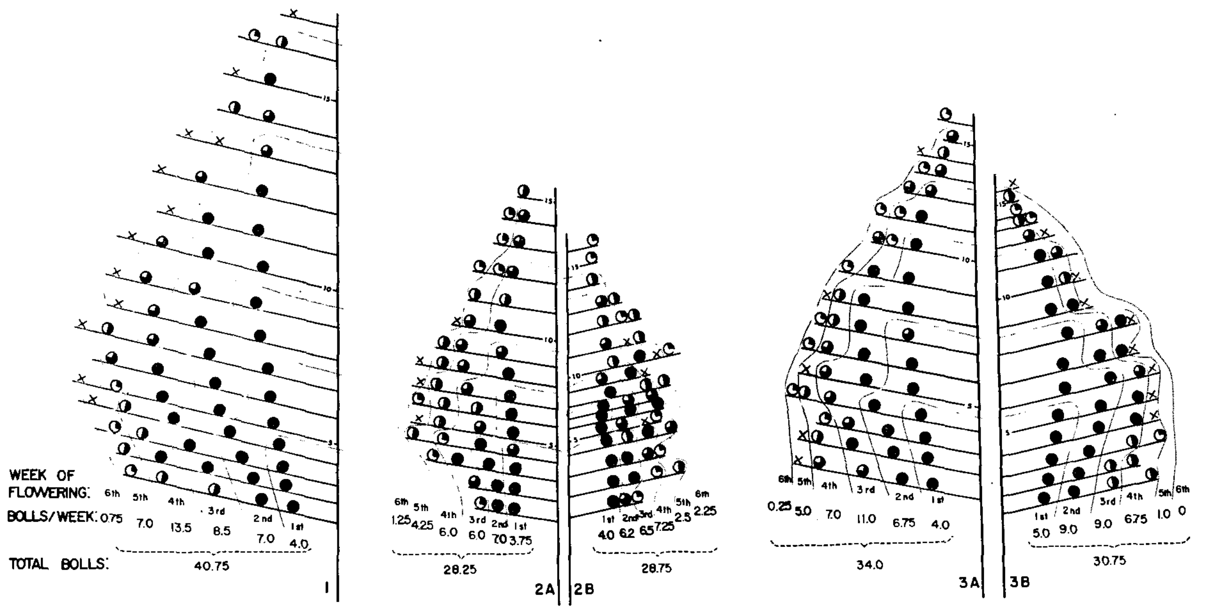

Figure 3. Plant diagrams to scale of average length of internodes, with all branches rotated to one side. Proportion of shading shows percent boll set at each node. "X" denotes flower in at least 3 out of 4 observations, but no boll set. (1) Unsprayed control. (2A–3B) CCC applications: (2) 2 weeks before flowering, (3) at onset of flowering; in concentrations of (A) 25 ppm and (B) 100 ppm.

Table 4. Effect of CCC treatments on cotton boll period,† by week of flowering. Data expressed as average number of days exceeding the corresponding boll period shown for control plants.

Application		Week of flowering						Aver.
Time†	ppm.	1	2	3	4	5	6	
A	25	3**	2*	2*	2*	3**	0	2*
	100	4**	6**	5**	4**	4**	2*	4**
B	25	1	2*	1	2*	3**	1	2*
	100	1	2*	2*	2*	3**	0	2*
C	25	0	0	0	0	2*	2*	1
	100	0	0	1	0	4**	2*	1
Control		44	43	43	43	42	43	43

*,** Difference from control significant at 5% and 1% levels. † Days from anthesis to boll opening. ‡ A - 2 weeks before flowering, B - at onset of flowering, C - after 2 weeks of flowering.

The main limitation of productivity was manifested in reduced boll set. This began 3 or 4 weeks after treatment and lasted 2 to 3 weeks. Also, reduction in seed cotton produced from each week of flowering began 2 to 4 weeks after treatment and lasted 1 to 5 weeks depending on time and concentration. The 2- to 4-day increases in average boll period would not materially delay maturity. However, in this case maturation occurred during the progressively longer days and increasingly higher temperatures of the greenhouse during the spring. Therefore, a slight increase in boll period under these conditions would be considerably extended in the field where bolls mature during increasingly shorter days and longer, cooler nights.

An interesting consideration is the possibility that CCC could be applied in combination or in sequence with a gibberellin (GA) in a balance of concentrations that would permit partial suppression of stem elongation without seriously affecting reproductivity. Wittwer and Tolbert (9) found that a compound closely related to CCC can neutralize the modifications in flowering of tomato caused by gibberellin A_3. They reported also (10) that certain combinations of CCC, indoleacetic acid (IAA), and gibberellin A_3 accelerated the growth of tomato ovaries over-and-above that caused by any combination of IAA and GA_3 alone.

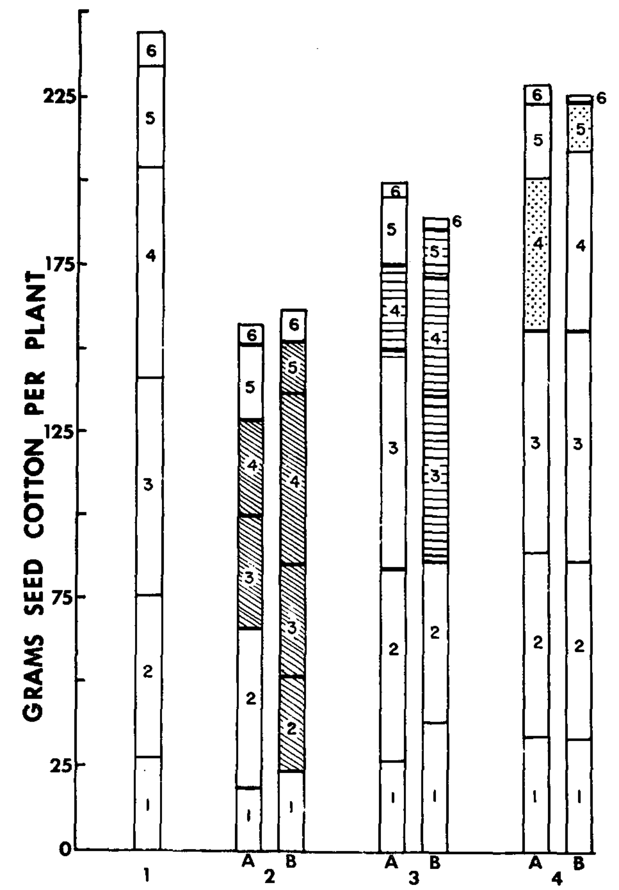

Figure 4. Total seed cotton production per plant, subdivided by week of flowering as shown by numerals in bars. Shading denotes production significantly less than on control plants. CCC applications: (1) Unsprayed control; (2) 2 weeks before flowering; (3) at onset of flowering; and (4) after 2 weeks of flowering. Concentrations (A) 25 ppm and (B) 100 ppm.

Vegetative growth, flower production, and fruit development of cotton occur simultaneously over a relatively long period. Manipulating chemical regulators to modify each of these therefore becomes more complex than dwarfing ornamentals early with CCC, to be followed later by a GA spray to produce an elongated inflorescence (4). Lockhart (5) concluded that CCC shows a complete interaction with gibberellin A_3 and should be called an antigibberellin. On the other hand, Kuraishi and Muir (3) found that CCC interacts more with IAA than with gibberellic acid. Halevy (2) reported recently that potassium gibberellate inhibits the activity of peroxidase and IAA oxidase whereas CCC and other growth retardants stimulate such activity; further, that the effect was in each case inversely correlated with hypocotyl elongation. He proposed that growth retardants interact with GA in IAA-oxidase systems and thus modify growth by affecting the auxin level of tissues. This could explain the reduced boll set following CCC treatment of cotton since auxin levels are involved in boll abscission.

SUMMARY

The effects of application time and concentration of CCC on size and fruiting responses of M 8948 cotton plants were observed under greenhouse conditions. Reduction of main stem and fruiting branch elongation resulted from treatment prior to or at onset of flowering. This was more pronounced with the earlier application and more with 100 ppm concentration than with 25 ppm. Restriction of plant size was accompanied by moderate reductions in rate of flowering, severe reductions in boll set and seed cotton production, and slight increases in boll period. These limitations in productivity usually became evident 2 to 4 weeks after treatment and persisted 2 to 5 weeks depending on CCC concentration and effect being measured. Application before or at onset of flowering reduced seed cotton production by approximately the same percentage as the reductions in plant height.

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