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# Effect of Time and Rate of Application of Two Growth Retardants on Growth, Flowering, and Yield of Upland Cotton[1]

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## ABSTRACT

**Six experiments were conducted at four locations in Israel in order to evaluate the effect of two growth retarding chemicals, CCC and CMH, on plants of Upland cotton, *Gossypium hirsutum* L. When sprayed during the first week of flowering, CCC at 50 and CMH at 480 g a.i./ha retarded the increase in height of cotton plants without adversely affecting lint yield or quality. These treatments caused a small reduction in flower production, but this was not associated with a decrease in yield. In some of the experiments, the increase in plant height following treatment was reduced by as much as 50%. Application of CCC at the rate of 100 g a.i./ha at the beginning of flowering significantly reduced lint yield in one experiment. Increasing the rate of CMH to 720 g a.i./ha produced no harmful effects.**

**When CCC or CMH were applied in the middle of the flowering period, they were less effective in reducing plant height. These results indicate that both CCC and CMH may be used to arrest excessive vegetative development of cotton plants, and that the optimum time of application is the beginning of flowering.**


***Additional index words:* CCC, CMH, *Gossypium hirsutum.***

EXCESSIVE vegetative growth of Upland cotton, *Gossypium hirsutum* L., is undesirable in most cases because it usually causes lodging and boll-rotting, and makes defoliation and mechanical harvesting more difficult. This growth may be caused by high levels of soil moisture or available nitrogen, or by climatic conditions. It may be arrested by modifying the cultural practices, but this is not always feasible. The possibility of using growth-retarding plant hormones for this purpose should therefore be investigated.

One of the well-known growth retardants, CCC (2-chloroethyl trimethylammonium chloride), was found by Thomas (4) to be effective on cotton plants growing in a greenhouse. He reported that when CCC was sprayed on cotton plants 2 weeks after the start of flowering, elongation of the main stem and fruiting branches was reduced. The rate of flowering was moderately decreased, but there were no effects adverse to the normal development of the bolls.

Singh (3) reported that application of CCC resulted in an increase of 20 to 45% in the lint yield of cotton plants grown under field conditions in India. On the other hand, De Silva (1) found in Uganda that CCC caused a reduction in the number of fruiting branches and in the lint yield of Upland cotton.

Zur, Marani, and Carmeli (5) found in Israel that CCC at rates of 50 and 100 g a.i./ha, when applied at the 2 to 3 square stages (42 days after planting), was effective in reducing the height of cotton plants, but also caused a marked decrease in the seed cotton yield. This was confirmed by Zur, Marani, and Karadavid (6), who also found that when CCC was applied at a rate of 50 g a.i./ha after the beginning of flowering, there was no decrease in the yield of seed cotton or lint. Higher rates of CCC, when applied at that stage, significantly decreased lint yield but were not more effective in reducing plant height.

Jung (3) reported that a new growth retardant, CMH (N-dimethyl-N-$\beta$-chloroethyl-hydrazonium chloride), was highly effective when applied to cotton plants. Results of experiments conducted in Israel (5, 6) indicated that CMH, when applied at rates of 480, 720, or 1440 g a.i./ha, retarded the growth of cotton plants without causing any significant reduction in the yield of seed cotton or lint.

Thus, CCC and CMH, when applied at suitable rates at the beginning of flowering. were effective in reducing plant height. The purpose of the experiments reported in the present paper was to test this conclusion under a wide range of environmental conditions and determine whether there were any deleterious effects to the cotton yields.

## MATERIALS AND METHODS

Six experiments were conducted at four locations in Israel in 1971, in commercial fields of Upland cotton.

Experiment 1 was located at Kefar HaNasi, in the area of the drained Hula Lake in the Upper Galilee, on a calcareous clay and peat soil with 47% organic matter. 'Acala 4-42' cultivar was sown on April 7. The field was irrigated twice (June 11 and June 30) with a total of 225 mm of water.

Experiment 2 was located at Bet Dagan, in the central coastal plain area, on an alluvial clay soil. Cultivar 'Acala SJ-1' was sown on April 20. A total of 310 mm of water was applied in three irrigations (June 24, July 19, and Aug. 5).

Experiments 3 and 4 were conducted in two adjacent fields at Hazor, in the southern coastal plain area, on an alluvial clay soil. Acala SJ-1 was sown on April 24. A total of 410 mm of water was applied in four irrigations (June 7, July 6, July 26, and Aug. 12) in Experiment 3, and of 320 mm in three irrigations (June 26, July 20, and Aug. 6) in Experiment 4.

Experiments 5 and 6 were conducted in two adjacent fields at Beror Hayil in the northern Negev region, on a silty loess soil. Acala SJ-1 was sown on April 8. A total of 410 mm of water was applied in four irrigations (June 12, July 9, July 25, and Aug. 10) in Experiment 5, and of 360 mm in three irrigations (on June 29, July 25, and Aug. 10) in Experiment 6.

Data of the meteorological conditions at the experimental sites are given in Table 1. Minimum temperatures were lower and maximum temperatures were higher at Kefar HaNasi than at the other locations during most of the season.

Spray applications were made at two stages of plant development in each experiment. The first stage was during the first week of flowering; the actual dates were June 28 (Experiment 1), July 2 (Experiments 2, 3. and 4) and June 27 (Experiments 5 and 6). The second stage was at the middle of the flowering period; the dates were July 14 (Experiment 1), July 12 (Experiment 2), July 18 (Experiments 3 and 4), and July 13 (Experiments 5 and 6).

In Experiments 1 and 2, CCC was sprayed at rates of 50 and 100 g a.i./ha and CMH at rates of 480 and 720 g a.i./ha on both application dates. In the other experiments only one rate

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Table 1. Meteorological conditions at experimental sites in 1971, monthly averages.

| | April | May | June | July | August | September |
|---|---|---|---|---|---|---|
| | | | Minimum temperatures, C | | | |
| Kefar HaNasi | 10.0 | 13.7 | 15.9 | 17.8 | 18.4 | 17.6 |
| Bet Dagan | 10.2 | 14.3 | 17.2 | 19.1 | 19.5 | 19.3 |
| Hazor | 10.0 | 14.8 | 17.3 | 19.4 | 19.7 | 19.5 |
| Beror Hayil | 10.5 | 14.5 | 17.2 | 18.8 | 19.8 | 19.7 |
| | | | Maximum temperatures, C | | | |
| Kefar HaNasi | 22.3 | 30.4 | 32.2 | 32.4 | 33.7 | 33.5 |
| Bet Dagan | 22.0 | 28.0 | 29.5 | 30.1 | 31.7 | 29.8 |
| Hazor | 22.1 | 28.5 | 29.2 | 29.7 | 30.8 | 29.2 |
| Beror Hayil | 21.7 | 27.9 | 29.3 | 29.8 | 31.5 | 29.5 |
| | | | Relative humidity, at 14:00 hours | | | |
| Kefar HaNasi | 50.8 | 34.9 | 37.0 | 42.6 | 41.6 | 38.4 |
| Bet Dagan | 55.2 | 49.4 | 54.5 | 55.9 | 54.0 | 56.2 |
| Hazor | 50.6 | 42.4 | 47.8 | 50.9 | 51.2 | 53.9 |
| Beror Hayil | 55.4 | 44.8 | 48.4 | 51.9 | 50.4 | 54.8 |

Table 2. The effect of growth retardants on the final height (cm) of cotton plants.

| Treatment | | | Experiment number | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Material | g a.i./ha | 1 | 2 | 3 | 4 | 5 | 6 | Avg |
| | Control | | 107 a* | 116 a | 123 a | 103 | 114 a | 110 | 112 |
| 1st | CCC | 50 | 86 b | 94 b | 99 c | 97 | 108 ab | 106 | 98 |
| | CCC | 100 | 81 b | 100 b | -- | -- | -- | -- | -- |
| | CMH | 480 | 89 b | 102 b | -- | -- | -- | -- | -- |
| | CMH | 720 | 88 b | 97 b | 99 c | 96 | 104 b | 102 | 98 |
| 2nd | CCC | 50† | 96 ab | 110 ab | 111 b | 99 | 110 ab | 103 | 105 |
| | CCC | 100 | 93 ab | 105 ab | -- | -- | -- | -- | -- |
| | CMH | 480 | 104 a | 103 ab | -- | -- | -- | -- | -- |
| | CMH | 720 | 100 a | 110 ab | 110 b | 100 | 106 ab | 106 | 105 |

* Figures followed by the same letter do not differ significantly by the Student-Newman-Keuls Multiple Range Test. There are no significant differences where no letters are given. † 62.5 g a.i./ha in Experiments 3, 4, 5, 6.

Table 3. The effect of growth retardants on the growth of cotton plants after the beginning of flowering.

| | | | Experiment number | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | |
| First measurement | | | Jun 28 | Jul 2 | Jul 3 | Jul 3 | Jun 24 | Jun 24 | |
| Last measurement | | | Aug 21 | Sep 1 | Aug 27 | Aug 27 | Aug 18 | Aug 18 | |
| Growth of the control, cm | | | 45 | 42 | 42 | 28 | 26 | 41 | |
| Treatment | | | | | | | | | |
| Date | Material | g a.i./ha | Growth as percent of the control | | | | | | Avg |
| 1st | CCC | 50 | 52 | 47 | 45 | 82 | 76 | 79 | 64 |
| | CMH | 720 | 57 | 56 | 43 | 81 | 66 | 66 | 62 |
| 2nd | CCC | 50 | 80 | 85 | 71 | 90 | 100 | 73 | 83 |
| | CMH | 720 | 83 | 85 | 67 | 99 | 82 | 72 | 81 |

of each material was applied on each date: CCC at 50 g a.i./ha on the first date and 62.5 g a.i./ha on the second date; CMH at 720 g a.i./ha on both dates. Applications with a knapsack sprayer were made in 400 and 600 liters of water per ha on the first and second spraying dates, respectively, in Experiments 1 and 2, and in 500 and 750 liters/ha, respectively, in the other experiments. The foliage was completely covered by the spray solution in each case.

In each experiment there were six replicates. In Experiments 1 and 2 the treatments were arranged in split plots, with the two spraying dates as main plots, and the two rates of each material and an untreated check as subplots. In each of the other experiments there were five treatments (two spraying dates of each material and an untreated check) arranged in randomized blocks.

Each plot consisted of four rows, with the two center rows used for yield determination and for other measurements and observations. The length of each plot was 10 m in Experiment 1, 6 m in Experiment 2, and 12 m in the other experiments. The rows were 1 m apart, with 8 to 10 plants per meter of row. The usual cultural practices were followed, and insect pests were kept under control. Seed cotton was harvested by hand picking on Sept. 23 and Oct. 17 in Experiment 1, Sept. 22 and Oct. 15 in Experiment 2, Sept. 9 and Oct. 15 in Experiments 3 and 4, and Sept. 7 and Oct. 10 in Experiments 5 and 6. Samples of 50 and 20 bolls were taken from each plot at first and second harvests, respectively, for determinations of boll size, lint percent, and lint quality. Lint yield was calculated from seed cotton yield and lint percent.

Plant height was measured several times in each experiment, on 10 random plants in each plot, from ground level to the tip of the main stem. The flowering pattern was determined by daily counts of flowers from two rows in each plot of Experiment 2, and from one row in the other experiments.

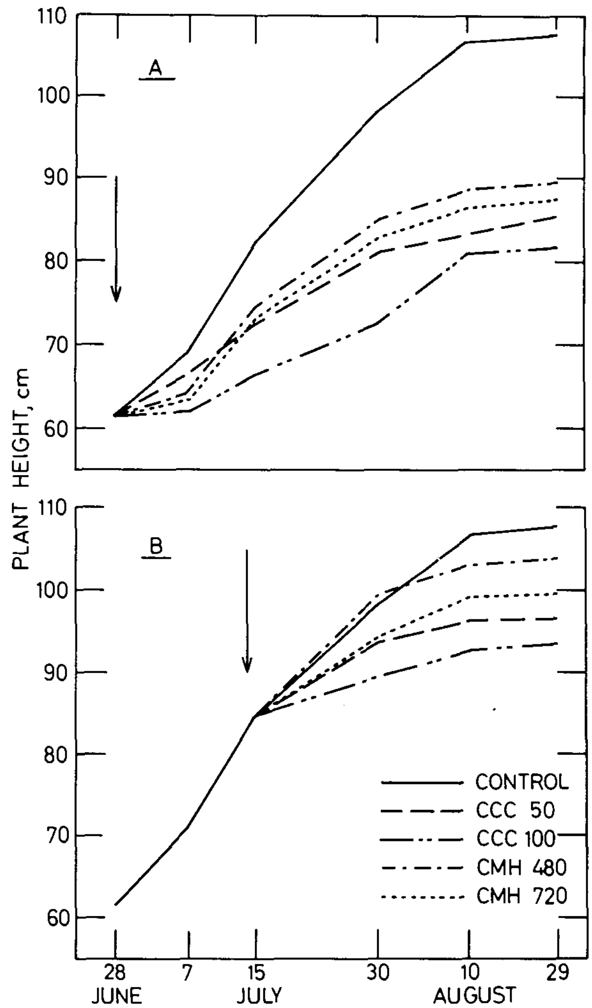


Fig. 1. The effect of growth retardants on the height of cotton plants in Experiment 1: (A) First treatment (June 28); and (B) Second treatment (July 14). Date of treatment is indicated by an arrow. Rates of application are given in grams active ingredient per hectare.

## RESULTS

The results of final plant height measurements are given in Table 2. The changes in plant height after the application of the growth retardants in Experiment 1 are given in Fig. 1. When CCC was applied at the beginning of flowering, it caused a prompt retardation of growth, and final plant height was significantly lower than that of the untreated plants in three experiments. The effect of CMH applied at the same time was similar to that of CCC, and the reduction of plant height caused by CMH was significant in four experiments. The effect of these materials, when applied at the middle of flowering, was less pronounced; the reduction in final plant height was statistically significant only in Experiment 3.

The increase in height from the beginning of flowering until final height had been reached is shown in Table 3. In Experiment 1, 2, and 3, where growth of the control plants averaged 40 to 45 cm during this period, CCC and CMH sprayed on the first date reduced plant growth by approximately 50%. The effect of the chemical retardants was less pronounced in the other experiments. Later applications were less effective than those made earlier in all experiments.

**Table 4. The effect of growth retardants on the total number of flowers per square meter of cotton plants.**

| Treatment | | | Experiment number and counting period | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | |
| Date | Material | g a.i./ha | Jun 25- Aug 11 | Jul 4- Aug 23 | Jul 3- Aug 13 | Jul 3- Aug 13 | Jun 22- Aug 18 | Jun 22- Aug 18 | Avg |
| | Control | -- | 68 | 78 | 96 a* | 111 | 89 | 105 | 91 |
| 1st | CCC | 50 | 72 | 75 | 82 b | 105 | 91 | 105 | 88 |
| | CCC | 100 | 65 | 77 | -- | -- | -- | -- | |
| | CMH | 480 | 65 | 81 | -- | -- | -- | -- | |
| | CMH | 720 | 71 | 77 | 85 ab | 100 | 87 | 104 | 87 |
| 2nd | CCC | 50† | 59 | 72 | 94 ab | 102 | 89 | 110 | 88 |
| | CCC | 100 | 68 | 73 | -- | -- | -- | -- | |
| | CMH | 480 | 65 | 75 | -- | -- | -- | -- | |
| | CMH | 720 | 70 | 74 | 89 ab | 110 | 91 | 109 | 91 |

*, † See footnotes to Table 2.

**Table 5. The effect of growth retardants on lint yield (kg/ha) of cotton plants.**

| Treatment | | | Experiment number | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Material | g a.i./ha | 1 | 2 | 3 | 4 | 5 | 6 | Avg |
| | Control | | 1,860 a* | 1,630 | 1,560 | 1,490 | 2,180 | 2,030 | 1,790 |
| 1st | CCC | 50 | 1,790 a | 1,680 | 1,570 | 1,530 | 2,060 | 2,050 | 1,780 |
| | CCC | 100 | 1,580 b | 1,560 | -- | -- | -- | -- | -- |
| | CMH | 480 | 1,870 a | 1,630 | -- | -- | -- | -- | -- |
| | CMH | 720 | 1,810 a | 1,680 | 1,650 | 1,550 | 1,990 | 2,130 | 1,800 |
| 2nd | CCC | 50† | 1,830 a | 1,560 | 1,580 | 1,520 | 2,080 | 2,200 | 1,800 |
| | CCC | 100 | 1,850 a | 1,580 | -- | -- | -- | -- | -- |
| | CMH | 480 | 1,900 a | 1,580 | -- | -- | -- | -- | -- |
| | CMH | 720 | 1,880 a | 1,640 | 1,610 | 1,510 | 2,100 | 2,140 | 1,810 |

*, † See footnotes to Table 2.

Data for total flower production during the main flowering season (Table 4) indicate no significant effects of the treatments in most cases. In Experiments 3 and 4 the total number of flowers was somewhat reduced by the application of CCC or CMH on the first date, but this was statistically significant only for CCC in Experiment 3. The weekly average of the daily number of flowers in these experiments (Fig. 2) indicated that reduction of flowering occurred in the third or fourth week of the flowering period and later, and that the effect of the second date of application was less pronounced than that of the earlier date.

Results for lint yield are given in Table 5. The application of growth retardants did not have significant effect on lint yield in most cases, but the application of 100 g a.i. of CCC per ha at the beginning of flowering reduced lint yield significantly in Experiment 1. In three experiments, some of the treatments caused a small reduction in lint percent, but no other effects were observed. The treatments had no effect on the earliness of the crop or the average weight of seed cotton per boll. In Experiments 1 and 2, in which lint quality was tested, the treatments had no effect on lint length, strength, or fineness.

## DISCUSSION

Cotton growers may prevent excessive vegetative development by controlling irrigation or nitrogen fertilization, or by other modifications of cultural methods. However, at locations where these methods are not effective, e.g. where ground water is near the soil surface or where there is abundant available nitrogen in the soil, chemical retardants may be utilized. Although such conditions prevailed in Experiment 1, irrigation prevented excessive growth of plants. The final height of the control plants did not exceed 123 cm in any experiment, they were not excessively tall or leafy, and no lodging or boll-rotting was observed. Therefore, our conclusions refer to the feasibility of using chemical retardants without encountering harmful effects on cotton yields.

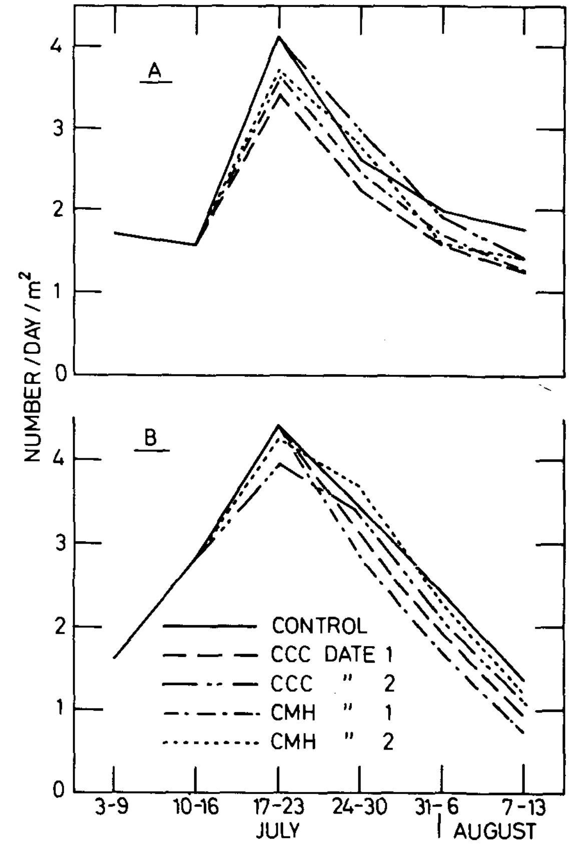


**Fig. 2. The effect of growth retardants on the daily rates of flowering of cotton plants in Experiment 3 (A) and Experiment 4 (B).**

Our results indicate that the most suitable time to spray CCC or CMH is at the beginning of flowering. This cannot, of course, affect prior growth, but previous experiments (5, 6) showed that an earlier application of CCC or CMH may cause substantial reductions in lint yield. Later applications, on the other hand, are less effective in reducing plant height.

When sprayed at the beginning of flowering, rates of 50 g a.i./ha of CCC and 480 or 720 g a.i./ha of CMH had no harmful effect on lint yield or its quality. The small reduction in flower number observed in some experiments was probably counterbalanced by less boll shedding because no decrease in lint yield occurred.

When the rate of CCC was increased to 100 g a.i./ha, a significant reduction in lint yield, which was probably associated with reduced boll retention, occurred in one of the experiments; similar results were obtained in previous work (6). Increasing the rate of CMH from 480 to 720 g a.i./ha had no harmful effects on lint yield, which is also in agreement with previous results (6). However, because these two rates did not differ significantly in their effect on plant height, 480 g a.i./ha is preferred.

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