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EFFECTS OF TIBA AND CCC ON COTTON (GOSSYPIUM HIRSUTUM L.)

by

Irfan Aşıcı

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I hereby recommend that this dissertation prepared under my direction by Irfan Asici

entitled Effects of TIBA and CCC on Cotton (_Gossypium hirsutum_ L.)

be accepted as fulfilling the dissertation requirement of the degree of Doctor of Philosophy

Robert E. Briggs — Feb. 6, 1973

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*This approval and acceptance is contingent on the candidate's adequate performance and defense of this dissertation at the final oral examination. The inclusion of this sheet bound into the library copy of the dissertation is evidence of satisfactory performance at the final examination.

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ABSTRACT

Field and laboratory studies were conducted in 1970 and 1971 to investigate the effects of two growth regulators, 2,3,5-triiodobenzoic acid (TIBA) and 2-chloroethyl trimethylammonium chloride (CCC) on cotton (*Gossypium hirsutum* L.) yield, boll and fiber characteristics, morphology, and leaf anatomy.

In 1970, cotton was produced with one and two rows per 102-cm bed for TIBA treatments. In 1971, the experiment was planted two rows 31 cm apart on a 102-cm bed. Studies with CCC were conducted with two rows per bed in both years. Six harvest periods were made in 1971 for fiber and boll determinations and a seventh harvest for yield.

High concentrations of TIBA reduced cotton yield. A moderate concentration of TIBA (4.94 g/ha) applied four times at 5-day intervals resulted in a nonsignificant yield increase. The number of spray applications affected yield. TIBA sprayed four times gave slightly more seed cotton than fewer or more applications although the effect was not significant.

TIBA had no significant effects on boll and fiber characteristics at the different harvesting periods, except the highest concentration which significantly increased lint per cent at the fourth harvest.

Leaf area and dry weight were increased nonsignificantly with a low concentration of TIBA.

TIBA inhibited cell differentiation in palisade and spongy parenchyma tissues.

There was a trend for decreased yield with increased concentration of CCC. The low concentration sprayed twice nonsignificantly increased yield.

Some boll and fiber characteristics were significantly affected by CCC. Seed obtained from CCC treated plants were larger and heavier than seed from the check treatment. Lint per cent and lint index were significantly increased from the early and late harvest periods. Fiber strength was significantly increased at Harvest 5. CCC also significantly increased fiber fineness at Harvest 1.

High concentrations of CCC nonsignificantly increased leaf area and leaf dry weight.

Plant growth was suppressed by CCC. CCC treated plants were shorter, had thicker stems, and darker green leaves than untreated plants.

CCC treatments resulted in the formation of incomplete secondary palisade layers which increased leaf thickness.

INTRODUCTION

The basic objective in crop production is to increase yield and to improve or maintain quality. Therefore, efforts have been made, using various breeding techniques and agronomic practices, to increase yield in cotton (Gossypium hirsutum L.) production.

Any technique or method that encourages flowering, fruit setting, and early boll maturation in cotton may result in higher yield and good quality lint and seed. Regulation of flowering and early boll maturation would be more advantageous to cotton producers in areas where rainfall occurs in the early fall or where the growing season is short. It would also be beneficial in reducing costs of late season insect control.

In the past decade, synthetic growth regulators have been used on agronomic and horticultural crops to alter flowering, fruit setting, maturation, and morphological characteristics. A few chemicals have been recommended as flower inducers in certain crops resulting in increased yield potential. However, there is little evidence that flower induction by these growth regulators can be repeated on a regular basis with similar results with cotton.

The aim of the present work was to investigate the effect of two growth regulators, 2,3,5-triiodobenzoic acid

(TIBA) and 2-chloroethyl trimethylammonium chloride (CCC), on yield, agronomic and morphological characteristics, and boll and fiber properties of cotton.

REVIEW OF LITERATURE

Physiological Effects of Plant Regulators

Two growth regulators, TIBA and CCC have shown potential for increasing yield in some crops (14, 25, 30, 34, 75, 80, 81, 96). However, further investigations will have to be made before the chemicals can be used commercially (88).

TIBA

In 1942, Zimmerman and Hitchcock (109) reported that TIBA had plant growth regulatory activity. Since then the physiological modifications caused by TIBA have been investigated on many different species (16, 47). However, the mechanism by which TIBA exerts its regulatory activity is not well known (77). TIBA is not an auxin (30) and normally negates the effect of indole-3-acetic acid (IAA). It may do this by competing for a carrier or by accelerating the destruction of IAA. Galston and Dalberg (31) concluded that TIBA enhanced the formation of the IAA-oxidase system. Thus, the loss of apical dominance from TIBA application was the result of low levels of auxin concentration (30).

Kamien and Skoog (49) and Hay (40) concluded that low concentrations of TIBA primarily affected the polarity of auxin, rather than the destruction of it. However, Aberg (2) indicated that low amounts of TIBA had weak auxin effects which might be due to a synergistic action upon residual amounts of the native auxin. He reported that high concentrations of TIBA, however, antagonized the effect of externally applied auxin and apparently also the natural auxin, because at higher amounts, TIBA caused a growth inhibition resulting in a toxic influence of a less specific nature, eventually leading to the death of cells that was not specifically related to the auxin mechanism. Inhibition of polar auxin transport by TIBA was determined in studies by many investigators (40, 46, 47, 84). Hay (40) reported that TIBA interference with the transport of auxin was in proportion with its concentration.

Experiments by Christie and Leopold (18) showed the relative entry and exit component of the transport systems from cells. TIBA inhibition of auxin entry was relatively weaker than the inhibition of exit from cells. The preferential inhibition of exit was attributed to the accumulation of auxin in TIBA treated sections.

Polar movement of auxin is generally considered to be a fundamental factor in apical dominance (3, 6, 28, 30). The results of many experiments (4, 40, 92) indicate that polarly transported auxin is an important factor in the control of axillary bud growth. Eliasson (28) concluded that inhibition of axillary bud growth could not be attributed to the amount of auxin only, but other considerations including the amount of growth hormone other than auxin being translocated and the availability of carbohydrates.

TIBA does not inhibit the translocation of auxin only. It also has interesting effects on plant apices where flower-buds are induced prematurely in an increased number (33). According to Thimann and Bonner (87), TIBA acted as a growth promoter as well as growth inhibitor, depending on its concentration.

Wardlaw (98) reported that TIBA treatment changed the shape of vegetative apex, leaf formation and growth, and subapical elongation of cells in tomato (*Lycopersicon esculentum* M.) plants. He observed that apical cells undergo a thickening of their walls and lose their regular arrangement. He believed that the amount of auxin in the distal cell group was destroyed or inactivated as a result of TIBA application. Whereas, in the inner regions, sufficient auxin remained to make growth possible. He concluded that suppression of growth by TIBA application took place in the most distal cells of the apex, while slow growth was in progress in the subjacent region. Hence, it resulted in unusual configuration and organization of the cells in tissues.

Dastur and Prakash (22) reported that the most visible effect of TIBA on cotton plants was an apparent increase in meristematic activity, even though it did not increase node production significantly.

CCC

In the last decade, a number of chemical compounds have been described as synthetic growth regulators. One of those, CCC, has the property of reducing plant growth (90). The most common response to CCC in plant growth is the reduction of stem elongation, enhancement of darker green color, and greater leaf thickness (1, 25, 44).

Many investigators have concluded that the response of plants to CCC could be overcome by treatment with gibberellin (GA) (60, 106, 107). Kuraishi and Muir (58) emphasized that CCC did not have an anti-gibberellin effect. On the basis of kinetic studies, Lockhart (60) described CCC as a GA antagonist which exerts its effect by reducing activity of GA in plant tissues. However, he did not explain whether CCC competed with GA for active sites, or was destroyed, or inactivated by interfering with GA biosynthesis. Ninnemann et al. (67) studied the CCC and GA interaction and observed that the amount of GA decreased as CCC concentration increased. They attempted to determine whether CCC inhibited GA biosynthesis or destroyed it. They suggested that no appreciable GA destruction took place on the basis that the amount of GA remained the same for a period of time after CCC application. Thus, they concluded that CCC inhibited the biosynthesis of GA, as was supported by Harada and Lang (38), and Dennis, Upper, and West (23).

Kende, Ninnemann, and Lang (51) reported that CCC suppressed GA formation almost completely in 3 to 7 days with concentrations as low as 10 μg/l. Thus, the growth retarding action of CCC on plants was explained by these workers in terms of its inhibitory effect on the biosynthesis of endogenous gibberellins. However, Berry and Smith (9) concluded that high concentrations of CCC act through an inhibition of protein synthesis rather than through a direct effect on endogenous gibberellin production. Therefore, the inhibition of chlorophyll synthesis by CCC in barley (*Hordeum vulgare* L.) leaves was attributed by Shewry, Pinfield, and Stobart (78) to the inhibition of protein synthesis. Humphries (45) found that CCC treatment delayed the time for total nitrogen and protein-nitrogen breakdown. He emphasized that CCC did not maintain protein content by affecting protein synthesis, but delayed protein hydrolysis due to less demands of the growing points treated with CCC. These results do not agree with those of Khan and Faust (52). Increased nitrogen content in tomato from CCC application was reported by Abdalla and Verkerk (1) to result from increased root system and root activity. According to Gaspar and Lacoppe (32), CCC acted at the nucleic acid level which resulted in accelerated catalase, peroxidase, and IAA oxidase activity in barley coleoptiles. Halevy (37) reported an increase in IAA oxidase activity in cucumber (Cucumis sativus L.) seedlings after CCC treatment, in addition to an interaction with GA. Thus, CCC interacts not only with GA, but IAA also (60). It has been proposed that the anti-gibberellic activity of CCC was due to lowering of the diffusible auxin level in the plant (54, 58, 92). Parkash and Lal (72) concluded that inhibition of growth by CCC in cotton was due to an accumulation of tryptophan.

No evidential support for the reduction of total sugar and nucleic acid content was found by Chinoy et al. (17) from treatment of peanut (Arachis hypogaca L.) seedlings with CCC. A high CCC concentration was found to be an inhibitor of amylase and lypase activity. El-Fouly and Garas (26) carried out a similar experiment with CCC in cotton and observed increased activity of amylase and invertase which was not due to the effect of CCC.

Shindy and Weaver (79) studied the translocation pattern of photosynthetic products from CCC treated grape vines (Vitis vinifera L.). They observed that the direction of translocation from lower leaves of untreated plants was downward, while it was upward in upper leaves. However, CCC treated plants showed bidirectional translocation from the lower leaves, but translocation was greatly reduced in upper leaves.

Parkash (71) determined that the activity of nitrate-reductase in seedlings of Upland cotton was reduced when treated with GA and increased with CCC. In a similar experiment, Singh (82) concluded that nitrate accumulation in cotton tissues was increased by CCC due to greater nitrate absorption by a well developed root system.

Effect of Growth Regulators on Plant Anatomy and Morphology

TIBA

Many reports in the literature describe the morphological effects of TIBA (8, 33, 64, 84). Despite the research in this field, there needs to be additional information about the development of observed abnormalities.

The main effect of TIBA on tomato leaves was the retardation of cell division and enlargement as reported by Bedesem (8). He reported that leaf curling was a result of a thickened vascular system and less cell division in the leaf lamina with the same characteristics observed on leaves from axillary buds. He also reported that the effect of TIBA on differential cell division during the early development of leaf primordia had gaps resulting in a discontinuous vascular bundle which filled with spongy parenchyma cells. It was concluded that TIBA functioned during formation of leaf primordia as well as during leaf enlargement which agreed with a study by Wardlaw (98).

Krause (56) observed that the xylem and phloem formed after TIBA treatment of soybeans (Glycine max [L.] Merrill) was mainly small with thick-walled cells. Wilton and Roberts (101) suggested that the reduction in size of vessels and the production of thick-walled xylem and phloem was the result of decreased cambial activity, which was in agreement with Krause's work. These workers also agreed that TIBA increased procambial activity. Krause (56) studied the amount of starch in soybean plants treated with TIBA and found that it was used or consumed more at the higher part of the plant for flower induction. In Krause's earlier work with Boke (57), they attempted to determine the effect of TIBA on soybean leaves 15 days after spraying. TIBA treatment induced double epidermal layers with the upper palisade cells about twice as thick as the lower, while high concentrations of TIBA increased the length of lower palisade cells.

Extensive research by Esau (29) indicated that characteristic differences between palisade and spongy parenchyma results from unequal growth in the various layers of the leaf, because cell division as well as cell enlargement and direction of cell expansion in the various layers of the leaf are different. Young treated leaves resulted in differential growth rates and expansion within the palisade and spongy layer during leaf enlargement (86) which induced ruffled leaves with a somewhat wrinkled lamina.

TIBA caused a disproportionate amount of growth and expansion of the bundle-sheath in soybean leaves in studies by Krause (56) and Krause and Boke (57).

CCC

Treating plants with CCC leads to a suppression of stem elongation, thicker and darker green leaves with shorter petioles, and increased stem thickness (46, 75). El-Fouly, Ismail, and Abdalla (27) reported that they did not observe any morphological changes during the experimental period in cotton plants treated with different concentrations of CCC.

Significant changes in the morphology of tomatoes by CCC treatment were observed by Van Bragt (93). Growth suppression took place up to 22 days after a single application of CCC at which time growth increased due to the absence of CCC. GA concentration was increased beginning at the fifth day after CCC application. Similar results were obtained by Reid and Carr (73) from the root of pea (*Pisum arvense* L.).

Tolbert (90) observed morphological changes in wheat (*Triticum vulgare* L.) plants from 5 to 15 days after treatment with CCC, but he did not observe any dark-green leaf color.

According to Cathey and Stuart (16), morphological changes in plants treated with CCC are affected by varietal differences as well as environmental factors, such as moisture, temperature, light intensity, and photoperiod. Only a high concentration of CCC was effective on chrysanthemums (Chrysanthemum morifolium R.) grown in the dark.

Studies indicate that very high concentrations of CCC inhibit root elongation in lettuce (Lactuca sativa L.) (53) and in grape (83). According to Lockhart (60) CCC did not inhibit root growth in pinto beans (Phaseolus vulgaris L.) even though stem growth was significantly suppressed. Results obtained by Abdalla and Verkerk (1) indicated that CCC enhanced root growth in tomato plants. Similar results were obtained by Singh (82) and Singh and Singh (80).

Wünshe (104), working with snapdragon (Antirrhinum majus L.) found that foliar application of CCC was more effective in growth inhibition than soil treatment. Low concentration of foliar spray stimulated plant growth while soil treatment had no effect.

Dyson (25) found that CCC increased the leaf area index, growth period, tuber size, and yield of potatoes (Solanum tuberasum L.).

Humphries (44) determined the morphological effect of CCC on radish (Raphanus sativus L.), white mustard (Sipanis alba L.), and tobacco (Nicotina tobacum L.) plants grown in water culture. CCC reduced leaf area at high concentrations while low concentrations increased it. High concentrations of CCC reduced chlorophyll, according to Cockshull and Van Emden (20) which resulted in chlorosis of brussel sprouts (Brassica oleracea L.) during a 2-week period after treatment. Leaf area and thickness were increased significantly by low amounts of CCC.

Parkash and Lal (72) observed reduced internode length in cotton after seed treatment with CCC. This suppression was more pronounced on hypocotyl elongation which was assumed to result from a reduction in cell division and elongation. Reduction in leaf size was predicted from lower nodes but not from upper ones. However, all leaves showed dark-green color, and increased thickness.

De Silva (24) observed inhibition of plant growth in cotton for 2 to 3 weeks following CCC treatment. He emphasized that spraying with high concentrations before flowering was more effective in growth inhibition than later applications. The number of sympodial branches was also reduced by CCC treatment. Zeevaart (106) observed reduction in the number of cells in the stem section of bindweed (Pharbitis nil C.) 39 days after CCC treatment, even though the sectional area was larger than the check as were the pith parenchymal cells as a result of thickened cells.

Effect of Growth Regulators on Flowering

TIBA

Zimmermann and Hitchcock (108) reported that TIBA applied to tomato plants at flowering caused ordinary vegetative buds to produce flowers and noticeable increased axillary growth. However, it did not induce similar results from spraying before or after flowering. Galston (30) found that TIBA did not induce flowering in soybeans when applied at flowering. Whiting and Murray (100), on the other hand, observed that the low concentrations of TIBA induced axillary structure in bean plants which resulted in increased flowers. Results presented by Thomas (89) indicated that TIBA sprayed on cotton before flowering reduced the number of flowers and the length of the flowering period. Anderson (4) pointed out the importance of time of TIBA application increased flowering in soybeans. He suggested that plant population could be increased due to compaction of plants treated with TIBA.

Variation in plant response to TIBA appears to be related to the physiological effect of temperature and soil moisture as well as time of application (7, 63). To evaluate the effect of TIBA on flowering, Hume, Tanner, and Criswell (42) studied the relationship of temperature and moisture, before and after flowering of soybeans. They reported that adequate soil moisture and normal temperature immediately after spraying were not necessary conditions to increase flower number, but the proper conditions for plant growth should be present during the pre-flowering period. Similar experiments were carried out by Ohki and McBride (68, 69), who reported that TIBA was more effective in increasing number of flowers when applied at floral initiation under pre- and post-wet conditions than any other time. However, the same experiment carried out in greenhouse conditions induced less flowering. They concluded that TIBA treatments followed by water stress had no effect on flowering compared with the check.

Vetter, Holden, and Albrechtsen (96) carried out experiments with TIBA on flax (Linum usitatissimum L.). They reported that high concentrations of TIBA successfully broke lateral bud dormancy, but reduced the number of flowers at the terminal and. They suggested that the best time of application to increase flowering with low concentrations of TIBA was after initiation of floral primordia.

Plant response to TIBA under different fertilizer levels has been investigated by many workers. Hicks, Pendleton, and Scott (41) observed no increased flowering in soybean with increased fertilizer and TIBA applications when soil fertility was at optimum level. Results obtained by Burton and Curley (14) from a similar experiment indicated that soybean plants responded significantly to TIBA under a high nitrogen fertilizer level when nodulation in soybean was increased by inoculation. Hartzook and Goldin (39) reported that TIBA not only reduced number of flowers but it also reduced pod size and weight in peanut.

An increased number of flowers in alfalfa (Medicago sativa L.) after TIBA treatment was observed by Hale (35, 36). He explained that the increase was due to greater tillering from low to moderate concentrations of TIBA.

CCC

Increased tillering of branching from CCC application in a number of plants contributes to the increased number of flowers and yield according to Cathey (15).

Bokhari and Youngner (12) reported that microscopic examination of barley seedlings revealed dormant tiller primordia, which could be broken by CCC treatment, resulting in increased flowering. They observed that flowering was delayed for several weeks with the highest CCC treatment which resulted in reduced yield.

Audus (6), Van Overbeek (94, 95), and others (55, 59) have concluded that diffusible auxin from terminal buds inhibited lateral bud growth. Okoloko and Lewis (70) reported that CCC increased the number of lateral buds in coleus (Coleus blumei B.) independent of the effect of GA and IAA. Enhancement of bud dormancy breakage by CCC was studied by Young and Cooper (105) in grapefruit (Citrus paradise M.). Bud growth was delayed at low temperatures with high concentrations of CCC or with multiple applications.

Zeevaart (106) investigated the effect of CCC in bindweed under short and long day conditions. All treatments reduced flower induction under the short-day period with high concentrations completely inhibiting terminal flowering. Flowering under long-day conditions increased at lower nodes with multiple CCC applications. Number of leaves and plant growth was reduced by increased concentrations and number of applications.

Comparing the nil effect of CCC in darkness against significant inhibition in the light, Wittwer and Tolbert (102) concluded that flower induction by CCC treatment was not the response of the plant to CCC, but rather the differential response to GA and IAA in the dark and light. They found that neither CCC nor GA altered the flowering period of soybeans grown in long- and short-day conditions. The same workers, in another study (103) reported that CCC could be used effectively in flowering induction in tomato plants in the greenhouse during the winter period. Hence, they suggested that field transplanting can be done early in the spring to stimulate or hasten the flowering period.

Abdalla and Verkerk (1) investigated the effect of CCC on tomato plants and reported that soil application of CCC reduced flower drop, and increased fruit set at high temperatures but not with normal temperatures. They suggested that the best time for enhancement of flowering and fruit set was spraying at anthesis. However, a late application was suggested to be more effective than an early application with high temperatures.

Cleland and Briggs (19) observed that when duckweed (*Lemna gibba* L.) was treated with CCC under long-day conditions, there was only slight inhibition of flowering with low concentrations, whereas, high concentrations strongly inhibited flowering.

Results presented by De Silva (24) indicated that two different concentrations of CCC treatments applied before, at, and after flowering reduced flowering in cotton in a positive relation with increased concentrations. He attributed this to a reduced number of flowering branches. Thomas (88) also observed a reduction in the flowering rate of cotton and concluded that reduced flower numbers was due to a growth suppression of sympodial branches.

Effect of Growth Regulators on Yield

TIBA

In reviewing data from experiments by many investigators, it appears that positive yield responses would be most likely to result from TIBA applications in some crops if the proper conditions are followed (4, 42, 96, 99).

Thomas (89), working with TIBA on cotton, reported that low TIBA concentrations applied as a foliar spray induced early flowering, but shortened the flowering period. Total seed cotton production was decreased as a result of the TIBA treatments. Dastur and Prakash (22) determined the effect of TIBA on yield in Upland and Asiatic (Gossypium arboreum L.) cotton with foliar and soil applications. They observed that seed cotton production was increased by low concentrations of TIBA as a foliar spray or soil drench in Upland but only low concentrations of soil drenching increased yield in Asiatic cotton.

According to Hicks et al. (41) soybean yield was increased by TIBA application due to the increased number of pods even though the number of seeds per pod and seed size were reduced. Burton and Curley (14) came to a similar conclusion, but yield from TIBA treated plants was lower than the check as a result of considerably smaller seed. They emphasized that any yield increase resulting from TIBA treatments would depend upon narrower rows, higher plant populations, adequate nutrients, and good cultural practices.

Colville (21) suggested that yield could be increased in soybean by TIBA if spraying was done when flowering was at the 1 to 5 per cent level. He emphasized that yield increase in soybeans was likely to occur due to earlier maturity in association with less plant lodging, resulting in easy and effective harvesting.

Considering the effect of temperature and soil moisture on vegetative growth in the period proceeding flowering, Hume et al. (42) concluded that TIBA may be very effective in increasing soybean yield if these conditions were readily adequate before and after flowering. They emphasized that late maturing cultivars should give a more consistent yield response to TIBA than earlier varieties. High temperatures would more likely be available during pre-flowering where late maturing cultivars grow. Tutt and Egli (91) found no significant yield increase from TIBA application to northern and southern soybean cultivars.

Muehlbauer and Miller (65) examined the relative effect of different concentrations and time of applications of TIBA on yield production in lentil (Lens culinaras L.) plants under field conditions. They reported that stage of application appeared to have no effect on the response to TIBA. TIBA treatments tended to reduce yield with the greater reduction occurring at the highest rates.

Vetter et al. (96) suggested that the ideal time to apply TIBA for yield increase in flax was 6 to 8 weeks after planting. High TIBA concentrations applied before and after blooming had detrimental effects on seed and oil yield. TIBA had no significant effect on seed and oil yield in soybeans, according to others (41, 99).

Hale (35) investigated the effect of different concentrations of TIBA on different alfalfa cultivars after cutting. Seed increase was observed from each cultivar treated with low concentrations; however, less than one-half ounce per acre of actual TIBA gave inconsistent results. He indicated that TIBA applications should be used in alfalfa for seed increase only, because of stunted plant growth. As Hale (36) cited in another report, seed increase in alfalfa from the low concentration of TIBA treated at early bloom was due to increased number of seed bearing stems and not from an increased number of seed per pod. Massengale and Medler (62) did not obtain any seed increase from TIBA treatment in alfalfa, due to the detrimental effects of very high concentrations of TIBA.

CCC

According to Cathey (15), any experiment to determine yield increase is only suggestive because experiments in successive years may not give similar results due to the variation in environmental conditions as well as technique and cultivar used.

Humphries, Welbank, and Witts (46) and Karchi (50) came to a similar conclusion that CCC increased yield in spring wheat. Yield increase was due to increased number of kernels which was attributed to increased tillering. Spike emergence was delayed up to 8 days by CCC treatment.

Bokhari and Youngner (11) and Vos, Dilz, and Bruinsma (97) compared soil and foliar application of CCC on wheat and came to different conclusions. Bokhari and Youngner found a yield increase from soil drenching while Vos et al. favored foliar application. Vos et al. also reported that late applications as well as high concentrations of CCC were less effective on lodging resistance and yield increase. Low to moderate concentrations before heading were suggested for best results.

Rudich, Karchi, and Pinthus (75) reported that late applications of CCC increased yield in wheat, while a combination of CCC and 2,4-D (2,4-dichlorophenoxyacetic acid) increased yield at early applications only.

Thomas (89) indicated that CCC was capable of shifting the normal pattern of flowering and fruiting without affecting seed cotton yield. Bhatt and Nathan (10) observed that initiation of floral buds was not affected by CCC treatments, but boll opening was delayed 4 to 10 days. Although number of bolls produced were not affected significantly, yield of seed cotton was decreased. They also observed reduction in fiber length, weight, maturity, and plant dry weight.

Singh (82) investigated the effect of various concentrations of CCC on Upland and Asiatic cottons at different locations. He concluded that late applications of high concentrations of CCC along with late planting reduced yield significantly. However, with a normal planting date, moderate application rates of CCC applied 75 to 80 days after planting increased number of bolls and reduced premature opening of bolls. Singh (81), in another investigation observed that low concentrations of CCC were very effective in increasing yield of Upland while only the higher concentration was effective in the Asiatic type.

Results presented by Zur, Marani, and Carmeli (110) indicate that foliar application of CCC to cotton at squaring time under field conditions resulted in delayed maturity and decreased seed cotton production.

According to Singh and Singh (80), 0.2 kg CCC per ha significantly increased boll weight and total seed cotton. They reported that CCC reduced the incidence of bollworm. CCC had no effect on ginning percentage, but only low concentrations gave the best yarn strength.

Flowering and boll maturation in cotton occurs over a period of time (13), during which environmental factors have continuing variation. Thus, yield reduction in cotton was attributed to variable response of plants to differential effects of environment as well as CCC (88). Therefore, it was pointed out that any moderate concentration and time of application was difficult to use in recommendations for yield increases in cotton.

MATERIALS AND METHODS

Studies were conducted at the University of Arizona Experiment Station at Marana in 1970 and 1971. The primary objective was to investigate the effect of different concentrations, number of applications, and intervals between applications of TIBA and CCC on yield, morphological and anatomical changes, and fiber characteristics of cotton. The experiments conducted in 1970 were designed primarily to determine the most effective concentration of growth regulators as well as other factors cited above.

Field preparation to plant cotton began after harvesting the previous crop, Sorghum (*Sorghum vulgare* L.) in 1970 and small grains in 1971. After plowing, 89 kg nitrogen fertilizer, and a preemergence herbicide combination of 5 liters Prefar [*O*,*O*-diisoprophyl phosphorodithioate *S*-ester with *N*-(2-mercaptoethyl) benzenesulfonamide], and 1.7 kg Caparol [*2*,*4*-bis(isopropylamino)-*6*-(methylthio)-*s*-triazine] per hectare were applied in Field C-3 in 1970, and 68 kg N, 1.2 liters Treflan [*a*,*a*,*a*-trifluoro-2,*6*-dinitro-*N*,*N*-diprophyl-*p*-toluine], and 1.4 kg Karmex [*3*-(*3*,*4*-dichlorophenyl)-*1*,*1*-dimethylurea] per hectare were applied in Field D-3 in 1971. The land was disked to incorporate these materials.

Single row beds 102 cm apart were formed with a lister and a bedshaper was used to form the beds for planting two rows per 102 cm bed. Following listing and shaping, the pre-plant irrigation was applied on March 22, and April 1 in 1970 and 1971, respectively. Approximately 46 cm water were applied during the preplant irrigation each year.

Acid delinted seed of the cotton cultivars 'Deltapine-16' and 'Stoneville-213' were planted on Pima clay loam soil at approximately 40 kg per hectare on April 10 and April 12 in 1970 and 1971, respectively. When two rows were planted per bed, the rows were 31 cm apart on the bed with a 71 cm spacing between two rows on adjacent beds.

The experimental designs during both years were randomized complete blocks with four replications. The plots were three-beds wide and 7.62 m long. The center bed was used for all observations with the outside rows as borders. Two experiments were planted two rows per 102-cm bed, and one experiment was planted one row per 102-cm bed in 1970. Both experiments in 1971 were conducted with two rows per bed. Hand thinning of all the plots was done when the seedlings were at the 4 to 6 leaf stage, to obtain plant populations of approximately 120,000 and 130,000 plants per hectare in 1970 and 1971, respectively. The normal farm schedule for insect control was followed during both seasons. As a layby herbicide, 1.12 kg/ha Karmex was applied on July 1, 1970, and 0.84 kg/ha on July 14, 1971.

After the preplant irrigation, water was applied when the plants showed symptoms for water need. Throughout the growing season about 40 cm of water were applied each year at approximately 10 cm of water at each irrigation on the following dates: June 12, July 9, August 5 and 28, 1970, and May 12, July 5, 21, and August 2, 1971. Total rainfall during the growing season was 20 cm in 1970 and 25 cm in 1971, most of which occurred during August 1971 followed by heavy boll-rot, particularly within the CCC treatments.

TIBA Treatments

The TIBA treatments used in the experiments in 1970 and 1971 are shown in Tables 1, 2, and 3 respectively.

A 3-gallon hand sprayer with three nozzles placed 32.5 cm apart was used for applying the chemical treatments (Fig. 1). Each nozzle had a 1.59 mm hole in a flat opening (Tee-Jet 8003). This spray-boom arrangement sprays one 102-cm bed. The middle nozzle was directed over the plant terminals in single-row beds. In double-row beds, the middle nozzle was directed over the middle of the bed. During chemical application, the spray boom was held at a constant distance over the tops of the plants (Fig. 1). Spraying was done between 9:00 a.m. and 12:00 noon, at times when the wind was essentially calm to eliminate drift.

The TIBA used in this study was obtained from the International Mineral and Chemical Corporation, Libertyville,

Table 1. TIBA treatments used in the two-rows per bed experiment in 1970.

Treat-ment	Rate of application (g/ha)	Number of applications	Intervals between applications (day)
1	4.94	4	7
2	12.35	4	7
3	24.70	4	7
4	24.70	4	7
5	12.35	6	7
6	4.94	5	5
7	12.35	5	5
8	Check		

Table 2. TIBA treatments used in the one-row per bed experiment in 1970.

Treat-ment	Rate of application (g/ha)	Number of applications	Intervals between applications (day)
1	4.94	4	7
2	12.35	4	7
3	24.70	4	7
4	4.94	6	7
5	4.94	5	5
6	Check		

Table 3. TIBA treatments used in the two-rows per bed experiment in 1971

Treat-ment	Rate of application (g/ha)	Number of applications	Intervals between applications (day)
1	2.47	4	7
2	4.94	4	7
3	9.88	4	7
4	2.47	4	5
5	4.94	4	5
6	9.88	4	5
7	4.94	3	7
8	Check		

Fig. 1. Spray equipment used for field application of TIBA and CCC.

Illinois. Sufficient spray solution was prepared to apply to all replications of a treatment (93 sq. m.) plus an additional quantity required for proper operation of the sprayer. The hand sprayer would not operate properly without maintaining a small amount of liquid at the bottom of the tank. On the basis of the 2.47 g/ha treatments, 0.19 ml of the TIBA solution was added to 3,480 ml water which was mixed with 26 ml wetting agent (X-77 Spreader). To formulate the solutions for the other treatments, only the amount of TIBA was increased.

The first application of TIBA began at the squaring stage on June 17, 1970, and June 23, 1971. The yield row(s) (middle bed) of each plot was sprayed first, then the border row(s). To allow for a uniform spray application of 3,480 ml solution per hectare, a constant walking speed was maintained with a beginning tank pressure of 2.8 kg/cm^2 (40 psi). After spraying one plot, the tank pressure was again raised to 2.8 kg/cm^2 before spraying the next plot, and this process was continued until all plots were sprayed. Spraying proceeded from the low to high concentration of a chemical. After spraying a treatment to all replications, the remaining liquid in the tank was discarded. The sprayer and nozzles were rinsed with water after spraying a treatment and before beginning the next treatment.

To eliminate the border effect of the yield rows, cotton plants within 61 cm from both ends of the plot were not harvested. Seed cotton was hand harvested four times in 1970 on the following dates: September 1, 21, October 10, and November 17. All undamaged open bolls were picked first, then damaged bolls. Seven harvests were made in 1971. The harvest dates for yield were August 23, September 3, 14, and 17, October 8 and 20, with a final harvest on November 28.

Ten undamaged open bolls were hand-picked at six periods from each plot at approximately 10-day intervals beginning August 23 to be used for determination of fiber and boll characteristics. Then the rest of the open bolls were hand-picked for yield. The seventh harvest was made for yield determination only.

All boll samples picked for fiber characteristics were kept separately in paper bags under controlled conditions (65% relative humidity and 22.2 C) until the samples were tested at the University of Arizona Cotton Laboratory. Laboratory analyses were made for fiber and seed characteristics and included: g/boll, lint per cent, lint index, seed index, fiber length (Fibrograph), fiber strength (Pressley index), and fiber fineness (Micronaire). In addition to the effect of TIBA and CCC, the rate of flower fertilization was determined in 1970 by studying unfertilized carpels of the bolls. All data were analyzed statistically at the University of Arizona Computer Center using the F test at the 5% level (85).

CCC Treatments

The CCC treatments used in 1970 are shown in Table 4. After reviewing the results obtained from the 1970 test trials, three concentrations under two different applications were used in 1971 (Table 5).

The CCC used in these experiments was a product of the American Cyanamid Company, Princeton, New Jersey. The formulation of the solution for CCC treatments was made on a ppm basis. To prepare the 25 ppm solution, 0.74 ml from the original solution containing 11.8% active ingredient was added to 3,480 ml water which was mixed with 26 ml wetting agent. To formulate the higher concentrations, only the amount of the original solution was increased. The conditions which applied to the TIBA treatments during spraying were also followed similarly for the CCC treatments.

The first spraying was made June 19, 1970, and June 24, 1971. Single spraying at full-flowering in 1970 was done on August 7.

Hand-harvesting of the CCC treatments in 1970 was made four times: September 11, October 1 and 21, and November 23. In 1971 harvest dates for yield were: August 27, September 8 and 20, October 4, 15, and 27, and the last on November 28. All other conditions applied to the TIBA harvesting were similarly followed for the CCC treatments. The same fiber and seed characteristics determined for TIBA were made for CCC treatments. All

Table 4. CCC treatments used in 1970.

Treat-ment	Rate of application (ppm)	Number of applications	Intervals between applications (day)
1	50	2	15
2	100	2	15
3	200	2	15
4	400	2	15
5	50	1	At full flowering
6	200	1	At full flowering
7	Check		

Table 5. CCC treatments used in 1971.

Treat-ment	Rate of application (ppm)	Number of applications	Intervals between applications (day)
1	25	2	15
2	50	2	15
3	75	2	15
4	25	3	15
5	50	3	15
6	75	3	15
7	Check		

data were analyzed statistically using the F test at the 5% level.

Leaf Sampling

Fully expanded leaves at the fourth node from the top of five plants within each replication of TIBA and CCC treatments were collected 15 and 30 days after the last application of chemical in 1971 on the basis of their appearance for uniformity, and with similar mid-vein length. The leaves were placed in an ice-chest and brought from the field to the laboratory. Each of the five leaf blades was separated from its petiole with a razor blade. The leaf blades were then placed flat in a transparent folder marked with the proper treatment and date identification. The leaves with curled lamina were cut into 3 to 5 pieces so they would stay flat in the folder. Leaf area was determined by the Xerox copy method. The folder was Xeroxed and the paper cut with a razor blade around the edge of each leaf copy. The paper was weighed to find the total area of five leaves in relation to the total weight and area of the entire Xerox paper.

Leaf dry weight was determined in order to find if there was any effect of growth regulators on leaf weight. The sampling method for leaf dry weight was similar to that explained for leaf area sampling. The leaf blades were placed in an air circulated oven and dried for 24 hours at

65 C. After drying, the bags containing the five leaf blades were placed into a desiccator until they were weighed.

Histological Studies

Histological methods were used to determine the effect of TIBA and CCC on anatomical changes in leaves. A fully expanded leaf at the fourth node from the top of a plant in each plot was collected in 1971. After collection, they were sectioned, saving a portion from the tip, center, and lower end of the leaf blade along the mid-vein of the leaf. The parts were then immediately immersed in a formalin-acetic acid-alcohol (FAA) solution. Following killing and a fixing period of over 48 hours, the sections were dehydrated separately in the tertiary-butyl-alcohol (TBA) series as outlined by Johansen (48). The sections were then embedded in parafin for sectioning at 10 micron with a rotary microtome. The sections were stained with fast green, and counter stained with orange-G. The slides were photographed under 10 x 12.5 magnification.

RESULTS

TIBA Treatments

Yield

Analyses of variance for the cumulative yield from seven harvests in 1971 from the TIBA treatments resulted in no significant differences (Table 6). High concentrations of TIBA tended to reduce yield slightly compared to the check. This yield reduction agreed with the results obtained from TIBA treatments used in single- and double-row experiments in 1970 (Tables 7 and 8). This indicated a reverse relation with increased concentration and number of applications of TIBA. Slightly higher yield than the check was obtained from the medium concentration of TIBA treatment in 1971 (Table 6). The same concentration of TIBA (4.94 g/ha) sprayed four times in single- and double-row experiments in 1970 also gave slightly higher yield than any other treatment or the check. This TIBA concentration sprayed three times (Table 6) or five and six times (Tables 7 and 8) yielded less than the TIBA treatments sprayed four times.

Fiber Characteristics

Analyses of 1971 data obtained from six harvest periods for the different seed and fiber characteristics indicated that only lint per cent at the fourth harvest had

Table 6. Cumulative yield (kg/ha) of seed cotton from TIBA treatments and the check obtained from seven harvest periods in 1971.

	TIBA treatments									
	1	2	3	4	5	6	7	8		
	Four appl. 7-day int.			Four appl. 5-day int.			Three appl. 7-day int.			
	Gram TIBA/ha/application									
Harvest	2.47	4.94	9.88	2.47	4.94	9.88	4.94	Check	EMS	F value
1	195.2	143.0	208.4	129.1	134.5	141.7	210.7	143.6	3463.3	0.60
2	439.2	354.2	488.5	364.4	380.9	381.3	368.6	428.9	9618.6	0.33
3	1411.5	1137.1	1484.4	1192.5	1572.0	1445.0	1233.1	1391.8	26257.2	1.62
4	2664.8	2345.7	2575.0	2315.6	2685.9	2496.6	2209.3	2645.0	41916.0	1.27
5	2913.5	2635.4	2689.3	2604.9	2897.5	2631.7	2484.5	2773.1	54480.5	0.52
6	3286.5	3377.0	3100.7	3238.2	3650.2	3098.2	2856.3	3236.8	103302.2	0.61
7	3403.3	3464.9	3262.5	3382.6	3682.6	3222.8	3006.8	3395.1	96468.7	0.49

Table 7. Cumulative yield (kg/ha) of seed cotton from TIBA treatments with two rows per bed and the check obtained from four harvest periods in 1970.

	TIBA treatments									
	1	2	3	4	5	6	7	8		
	Four appl. 7-day int.			Six appl. 7-day int.		Five appl. 5-day int.				
	Gram TIBA/ha/application									
Harvest	4.94	12.35	24.70	4.94	12.35	4.94	12.35	Check	EMS	F value
1	722.6	868.9	658.9	662.3	555.4	815.0	569.4	565.5	16672.3	0.71
2	2165.4	2114.7	1850.1	1900.7	1767.0	2070.0	1912.2	1911.1	48230.3	2.02
3	3868.2	3434.2	3212.8	3756.0	3231.5	3819.1	3624.2	3713.1	54442.8	2.25
4	3993.2	3530.9	3458.5	3948.9	3404.5	3921.6	3823.9	3968.6	4104.5	0.84

Table 8. Cumulative yield (kg/ha) of seed cotton from TIBA treatments with single row and the check obtained from four harvest periods in 1970.

	TIBA treatments							
	1	2	3	4	5	6		
	Four appl. 7-day int.			Six appl. 7-day int.	Five appl. 5-day int.			
	Gram TIBA/ha/application							
Harvest	4.94	12.35	24.70	4.94	4.94	Check	EMS	F value
1	559.7	804.3	820.4	690.5	780.3	571.0	22309.16	1.53
2	2146.7	2380.2	2065.7	2240.0	2364.9	2149.4	10502.4	0.67
3	3716.8	3589.7	3011.4	3505.9	3642.4	3511.8	38744.9	2.61
4	3833.2	3732.4	3184.9	3622.1	3697.5	3602.3	3745.8	0.96

significant differences at the 5% level according to the F test. The other seed and fiber characteristics including grams/boll, lint index, fiber length, strength, and fineness were not significantly different at any harvest.

The mean lint per cent values from the fourth harvest are shown in Fig. 2. The least significant difference (LSD) test (85) indicated that the mean values of Treatments 1, 3, and 6 were significantly higher at the 5% level than the check, Treatment 8. Treatments 4, 5, and 7 gave higher values than the check but were not significant. Only the second treatment had slightly lower lint per cent than the check.

Lint per cent for the six-harvest periods from TIBA Treatments 1, 2, and 3 sprayed four times at 7-day intervals and the check are shown in Fig. 3. Treatment 3 gave higher (non-significant except at Harvest 4) values than the check at all harvests except the third when they were nearly identical. All treatments including the check had higher lint per cent at the first three harvests and continually decreased after the third harvest with the exception of Treatment 2, which increased slightly between Harvests 5 and 6. Significant differences between treatments at the fourth harvest can be observed in Fig. 3.

Lint per cent values from six-harvest periods from Treatments 4, 5, and 6 sprayed four times at 5-day intervals and the check are shown in Fig. 4. Treatment 4 showed a

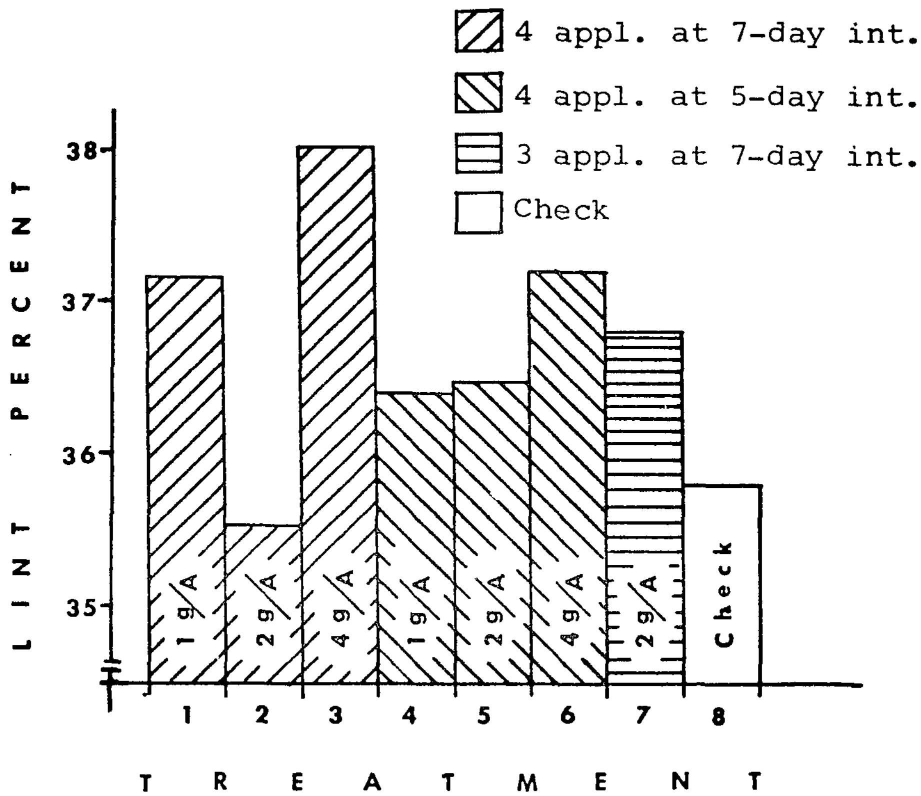


Fig. 2. Lint per cent from the fourth harvest of seven TIBA treatments and the check -- The LSD value at the 5% level was 1.22.

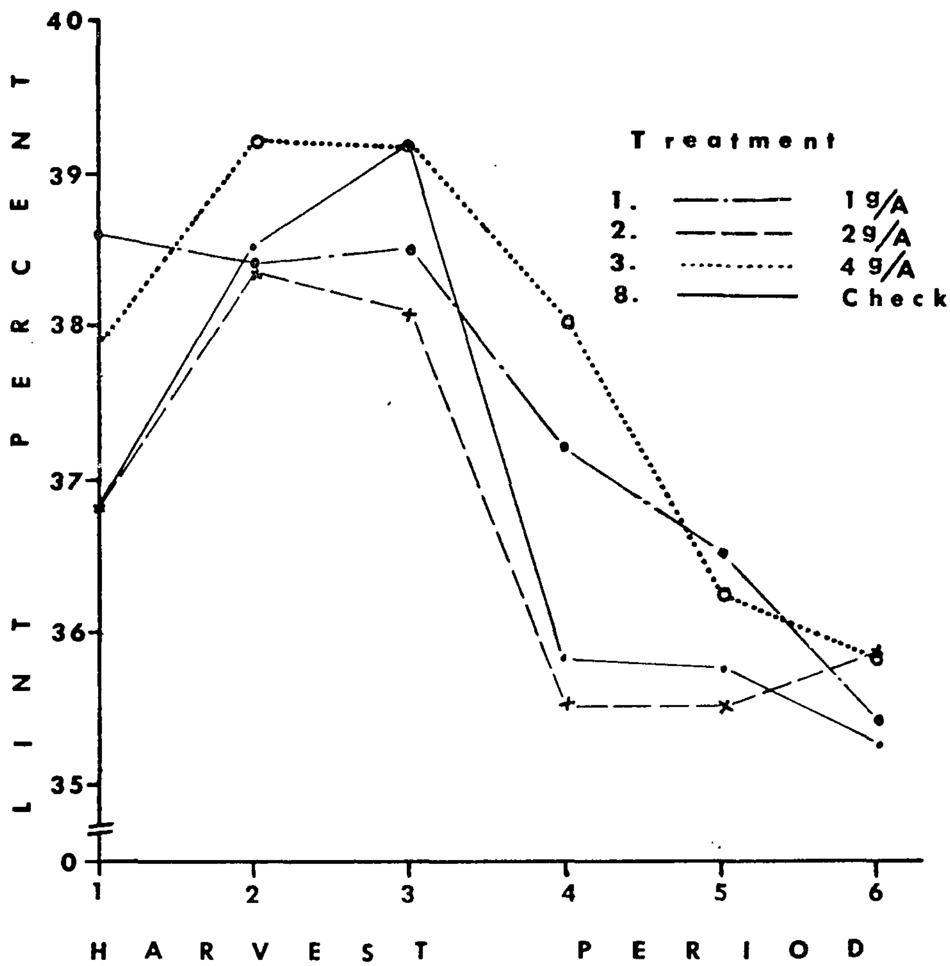


Fig. 3. Lint per cent from six harvests of three TIBA treatments sprayed four times at 7-day intervals and the check.

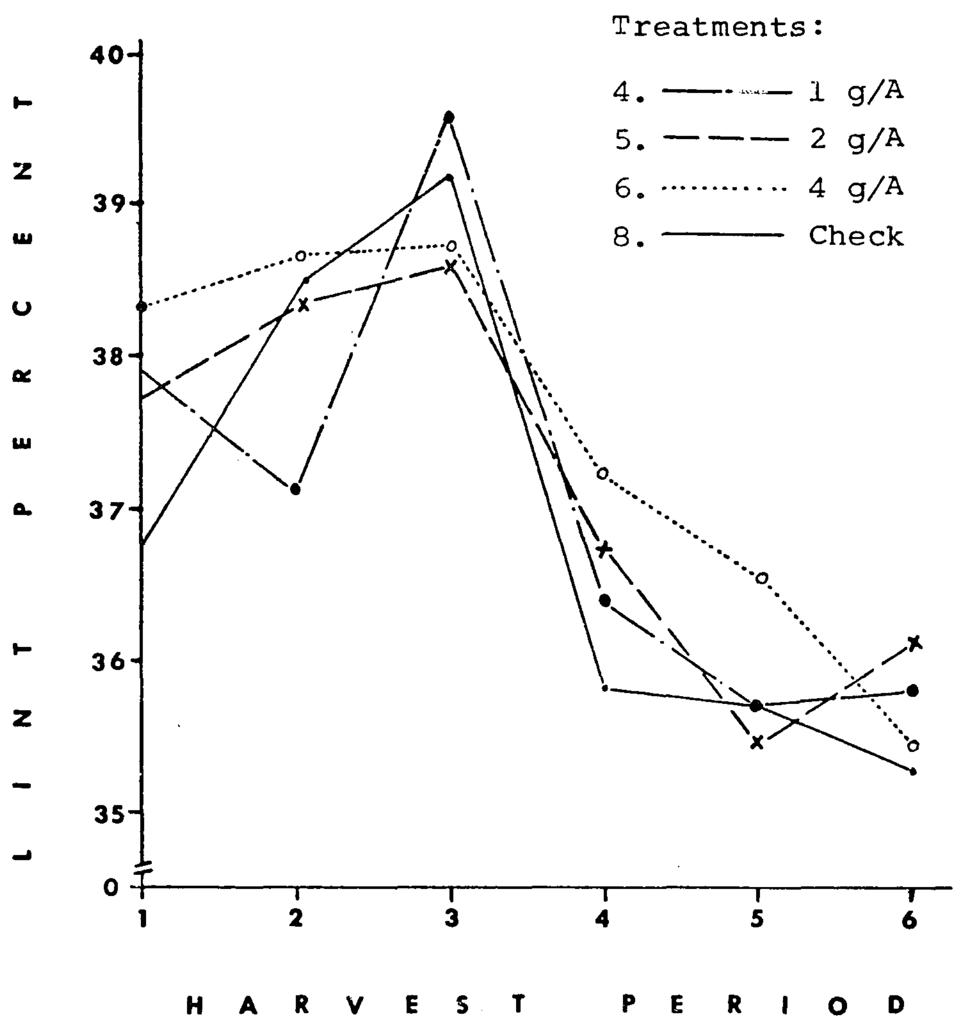


Fig. 4. Lint per cent from six harvests of three TIBA treatments sprayed four times at 5-day intervals and the check.

large increase in lint per cent from the second to the third harvest for some unexplainable reason. Treatment 6 gave higher values at four of the six harvests than any other treatment or the check. Although slightly higher lint per cent was obtained from high concentrations of TIBA, there appeared to be no direct relationship of increased TIBA concentration with either the 7- or 5-day treatments.

The effect of various TIBA treatments on fiber length over six harvest periods is shown in Fig. 5. Treatments 1, 2, and 3 gave slightly longer lengths at the early harvests (Fig. 5A) but showed greater fluctuations at late harvests compared with the check. Treatment 2 was similar to the check treatment throughout all harvests. This was also true for Treatment 5 which is the same TIBA concentration but sprayed at 5-day intervals (Fig. 5B). Figure 5 shows how fiber length usually increased slightly until the fifth harvest with a slight reduction at the sixth harvest, with the exception of Treatment 3.

Fiber fineness values from six harvests of TIBA Treatments 1, 2, and 3 sprayed four times at 7-day intervals are shown in Fig. 6. All treatments were similar to the check at the first five harvests with the exception of Treatment 1 which had slightly lower fiber fineness at Harvests 2 and 3. All treatments had higher fineness values than the check at Harvest 6. No relationship was observed between increased fineness and TIBA concentration, but the

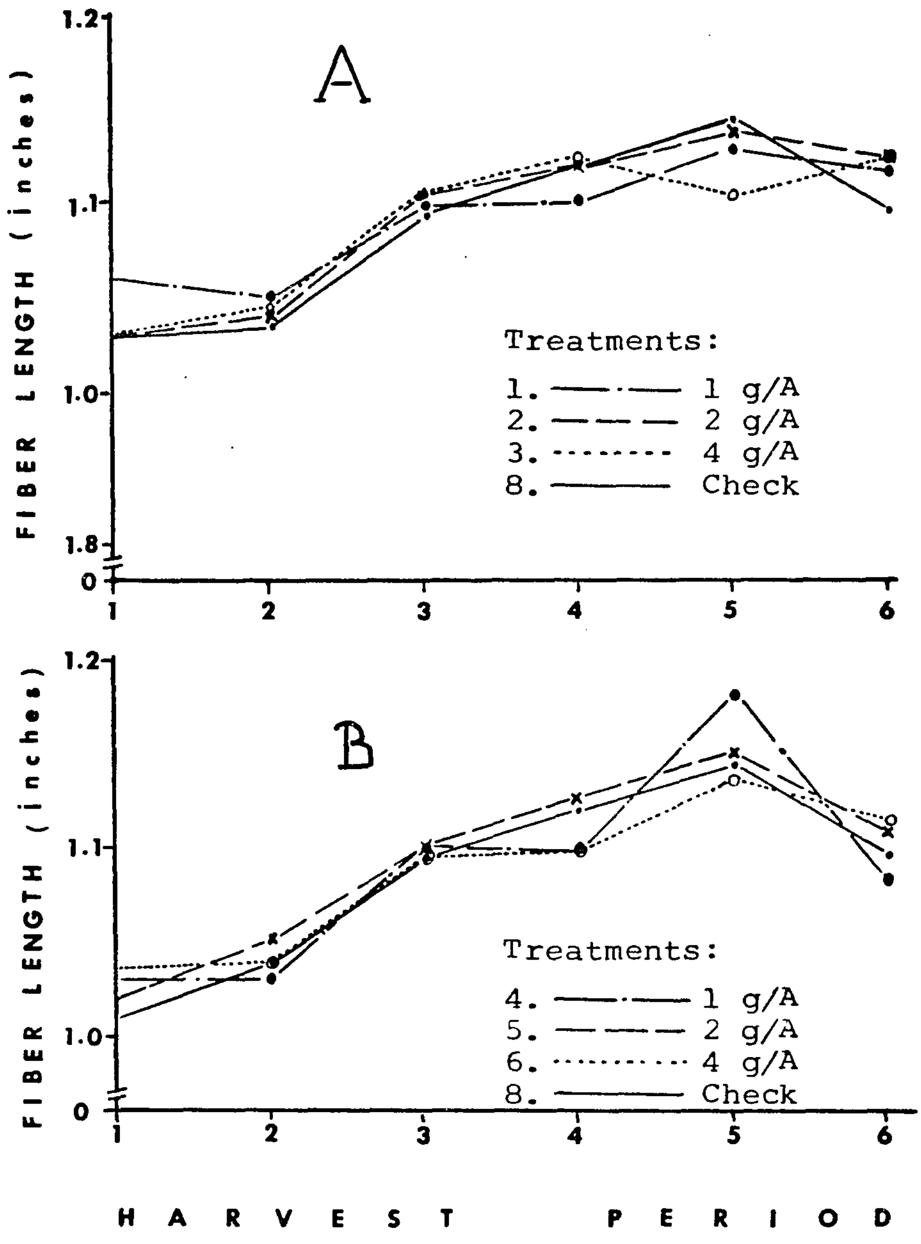


Fig. 5. Fiber length from six harvests of three TIBA treatments sprayed four times at 7-day(A) and 5-day intervals (B) and the check.

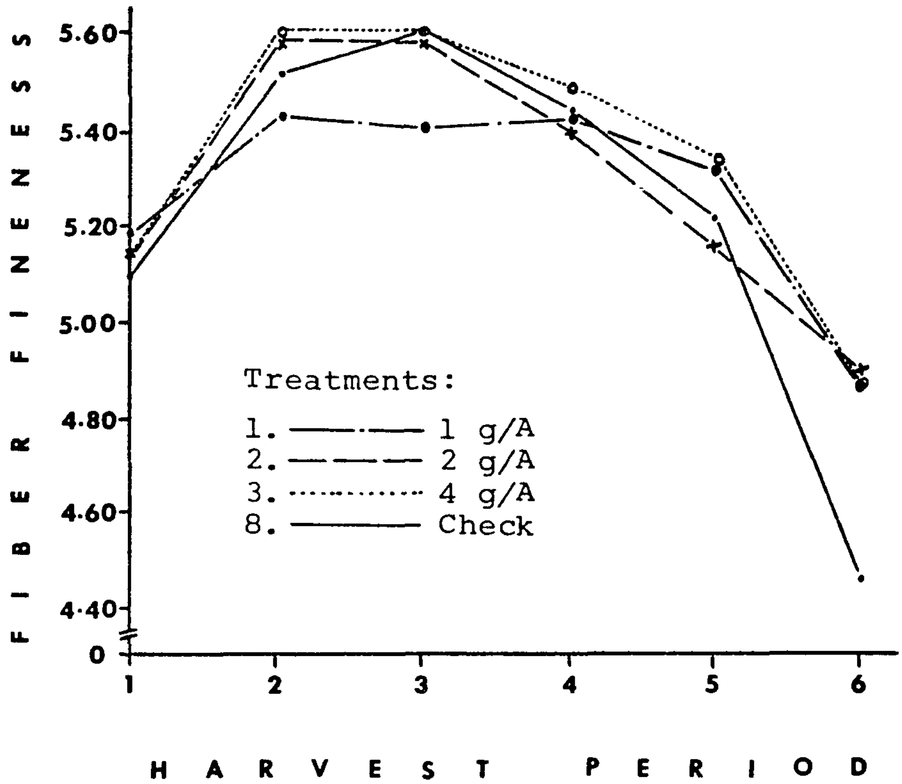


Fig. 6. Fiber fineness from six harvests of three TIBA treatments sprayed four times at 7-day intervals and the check.

highest concentration resulted in slightly higher fiber fineness throughout all harvest periods with the exception of Harvest 3.

TIBA Treatments 4, 5, and 6 sprayed four times at 5-day intervals are shown in Fig. 7. TIBA application at 5-day intervals reduced fiber fineness at mid-harvest more than the 7-day interval treatments. Again, no relationship was observed between increased concentration of TIBA and fiber fineness.

It is a normal occurrence that late maturing cotton generally gives lower fiber fineness values (5). All TIBA treatments sprayed at either 5- or 7-day intervals resulted in higher fiber fineness values than the check at the late harvest although the differences were not significant.

CCC Treatments

Yield

Cumulative seed cotton yield from six CCC treatments and the check obtained from seven harvest periods in 1971 are recorded in Table 9.

Analyses of variance made separately for the cumulative yield for each harvest gave significant differences at the 5% level from the second harvest only. The LSD test indicated that all treatments gave significantly higher yield than the check, except Treatment 3.

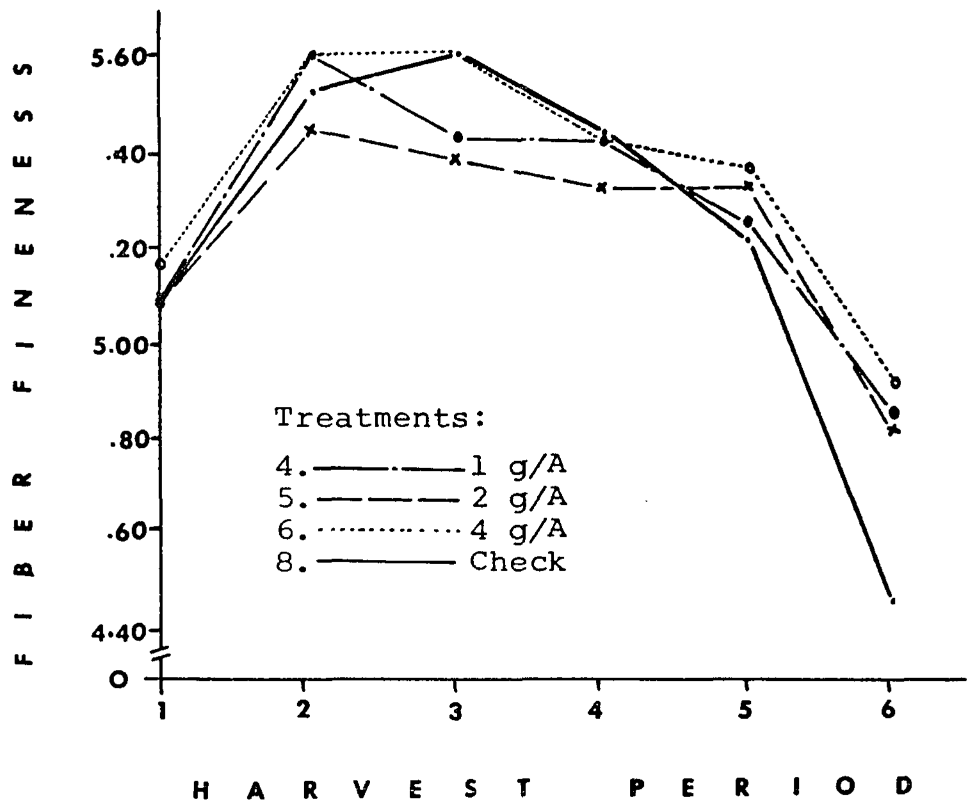


Fig. 7. Fiber fineness from six harvests of three TIBA treatments sprayed four times at 5-day intervals and the check.

Table 9. Cumulative yield (kg/ha) of seed cotton from CCC treatments and the check obtained from seven harvest periods in 1971.

	CCC treatments								
	1	2	3	4	5	6	7		
	Two appl. 15-day int.			Three appl. 15-day int.					
	PPM/application								
Harvest	25	50	75	25	50	75	Check	EMS	F value
1	318.6	562.6	285.9	455.9	463.0	414.4	293.6	9578.9	1.9
2	1132.3	1327.3	967.4	1250.8	1224.8	1273.0	865.5	19001.1	2.64*
3	2030.4	2115.5	1716.8	1946.2	1950.1	2112.3	2016.1	58429.9	0.54
4	2250.5	2301.5	1912.4	2173.1	2125.1	2288.5	2184.4	53953.1	0.52
5	2579.0	2518.3	2165.9	2475.9	2390.9	2517.1	2361.6	61945.3	0.51
6	2944.7	2935.8	2808.3	2962.8	2930.6	2961.1	2760.9	53019.6	0.20
7	3532.7	3296.3	3215.2	3353.3	3171.9	3208.6	3252.8	49443.2	0.49

*Harvest period was significantly different at the 5% level.

Results shown in Table 9 indicate that there was a trend for increased yield, particularly from the treatment with the lowest concentration of CCC sprayed twice. The same concentration sprayed three times gave slightly less total yield than two applications, but it was still slightly higher than the check although not significant.

Yield reduction showed a negative relationship with increased concentration and number of applications of CCC. Results obtained from CCC treatments in 1970 (Table 10) agreed with the 1971 results. Again, a trend was indicated for higher yield from low CCC concentrations while the highest concentrations showed non-significant yield reductions.

Fiber Characteristics

Analyses of variance of data obtained from six harvest periods in 1971 indicated that CCC had a greater effect on fiber characteristics than TIBA.

Boll weight designated as g/boll resulted in significant differences in the second and sixth harvest periods according to the F test (Fig. 8). The mean values of treatments from the second harvest were checked by the LSD test, and found that none of them were significantly different from the check. On the other hand, all treatments at the sixth harvest had significantly higher boll size than

Table 10. Cumulative yield (kg/ha) of seed cotton from CCC treatments and the check obtained from four harvest periods in 1970.

	CCC treatments								
	1	2	3	4	5	6	7		
	Two appl. 15-day int.				One appl. at full flowering				
	PPM/application								
Harvest	50	100	200	400	50	200	Check	EMS	F value
1	1033.6	1000.1	922.4	561.1	1011.5	923.1	867.8	12207.3	0.71
2	3336.3	3174.6	2906.4	2347.1	3238.9	3098.9	2923.8	42876.3	2.42
3	4058.1	3866.6	3472.2	3147.2	4019.5	3818.0	3868.3	8430.6	0.47
4	4144.5	3983.6	3593.5	3349.0	4085.1	3866.9	3977.1	1175.8	0.09

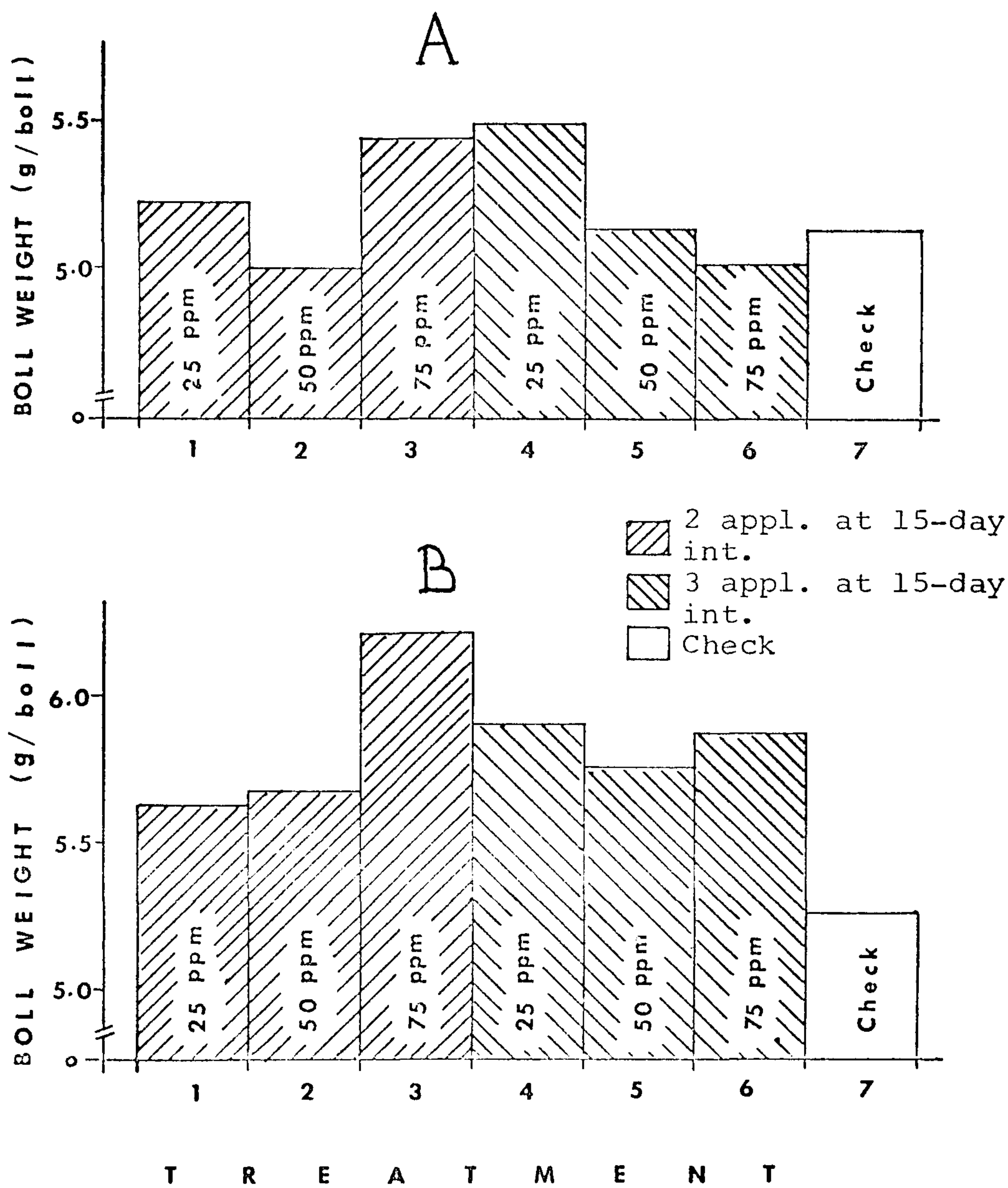


Fig. 8. Boll weight from the second (A) and sixth (B) harvests of six CCC treatments and the check -- The LSD values at the 5% level at the second and sixth harvests were 0.81 and 0.32, respectively.

the check. Treatment 3 resulted in higher boll weight than any other treatment.

To compare the CCC treatments sprayed twice with the check over the first six harvest periods, boll weights are plotted in Fig. 9. It is interesting that boll weight from any treatment including the check was lowest at the fourth harvest, while it increased at Harvests 5 and 6. Toward the end of the flowering cycle, CCC treated plants resumed growth. This was first observed in the treatments sprayed with low CCC concentrations. Treated plants remained green for a long time during which photosynthetic activity was probably more significant than the control plants as explained by Dyson (25). Although CCC treated plants remain green, first boll opening was observed 3 to 4 days later than the check. A similar observation was reported by Bhatt and Nathan (10). The delay in boll maturation caused heavier bolls. Seed obtained from CCC treated plants were larger and heavier than the check. Similar results were obtained by Singh (82).

Boll weight results obtained from six harvest periods of CCC Treatments 4, 5, and 6 sprayed three times at 15-day intervals are shown in Fig. 10. All CCC treatments at Harvests 5 and 6 had slightly larger boll size than the check, although the differences were significant only at Harvest 6.

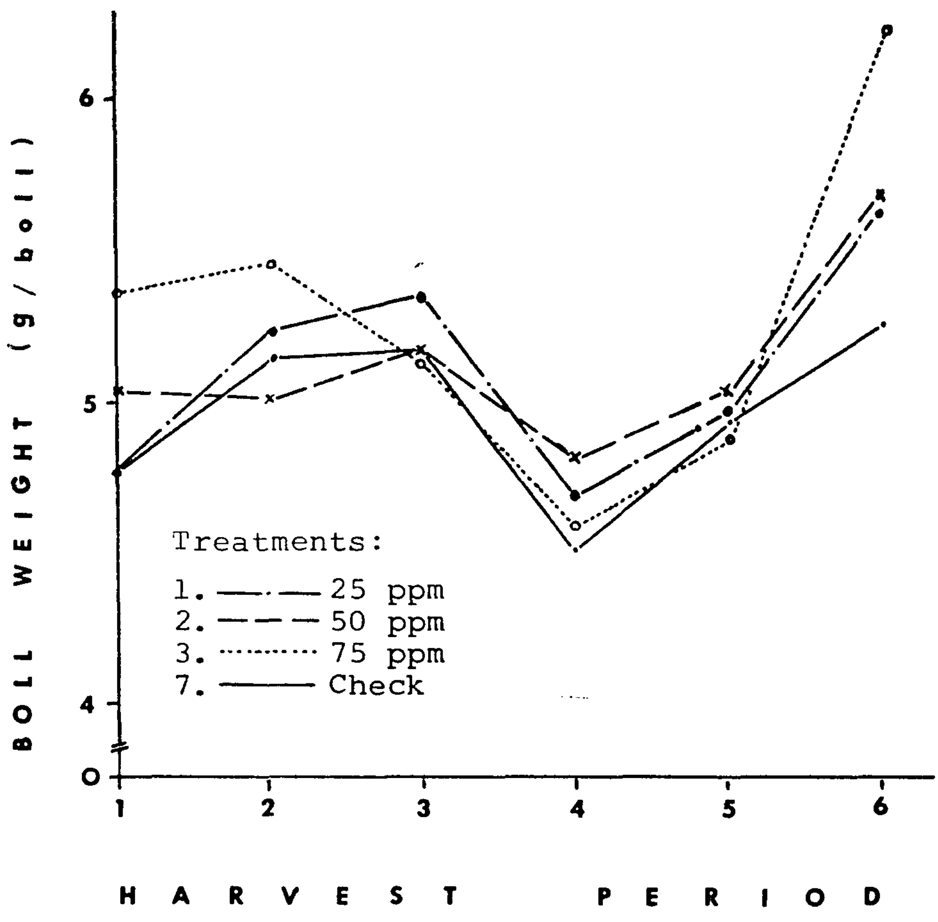


Fig. 9. Boll weight of three CCC treatments sprayed twice and the check treatment from six harvest periods.

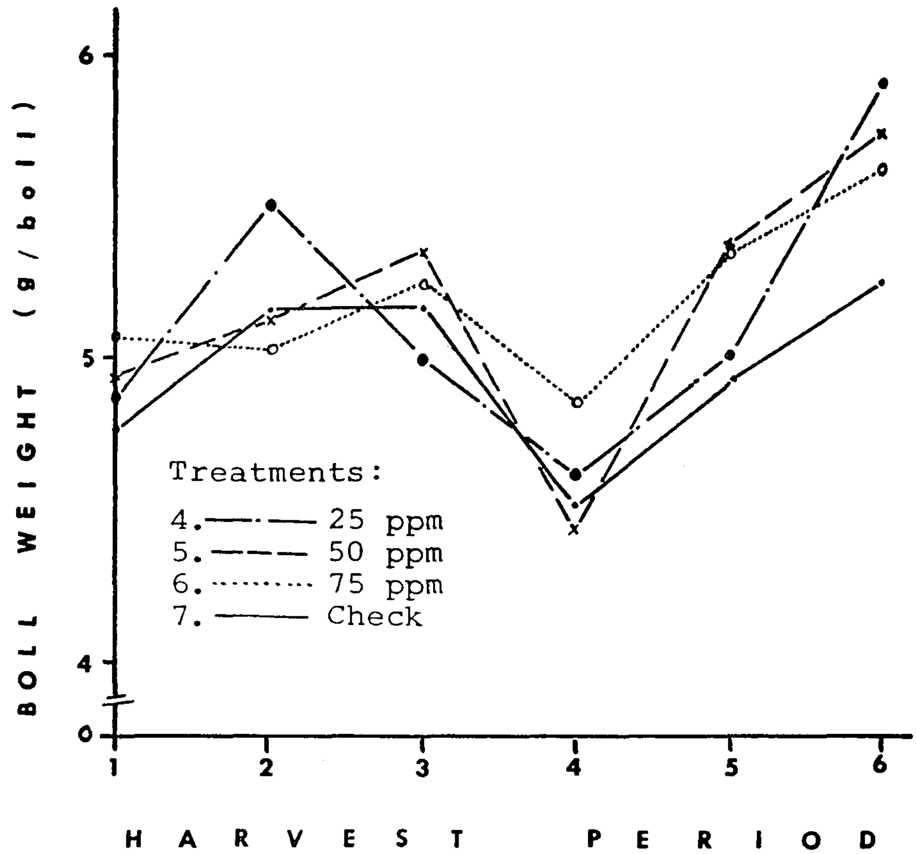


Fig. 10. Boll weight of three CCC treatments sprayed twice and the check treatment from six harvest periods.

No consistent relationship was observed between boll weight and concentration of CCC. It is interesting to note that the CCC treatments resulted in a trend of larger boll weight than the check at nearly all harvest periods. Boll weight was always less at the fourth harvest for all treatments (Figs. 9 and 10). All CCC treatments and the check showed an increase in boll weight from Harvests 4 to 6.

Analyses of variance for lint per cent resulted in significant differences at the third and sixth harvest periods which are shown in Fig. 11. Treatments 3 and 5 from the third harvest had significantly lower lint per cent than the check. Treatments 1, 2, 4, and 6 were not significantly different (Fig. 11A). Treatment 6 was the only treatment significantly different than the check from the sixth harvest (Fig. 11B).

To compare CCC Treatments 1, 2, and 3 sprayed twice and the check, lint per cent from six harvest periods is plotted in Fig. 12. Treatments 1 and 2 were similar to the check until the fourth harvest, and then were slightly higher than the check. Treatment 3, the highest CCC concentration, always had lower lint per cent than the check at all harvests. The spread in lint per cent was greater from mid and late harvests than from early harvests.

Lint per cent from CCC Treatments 4, 5, and 6 at six harvest periods showed slightly lower lint per cent than the check, with the exception of Treatment 4 at the fifth and

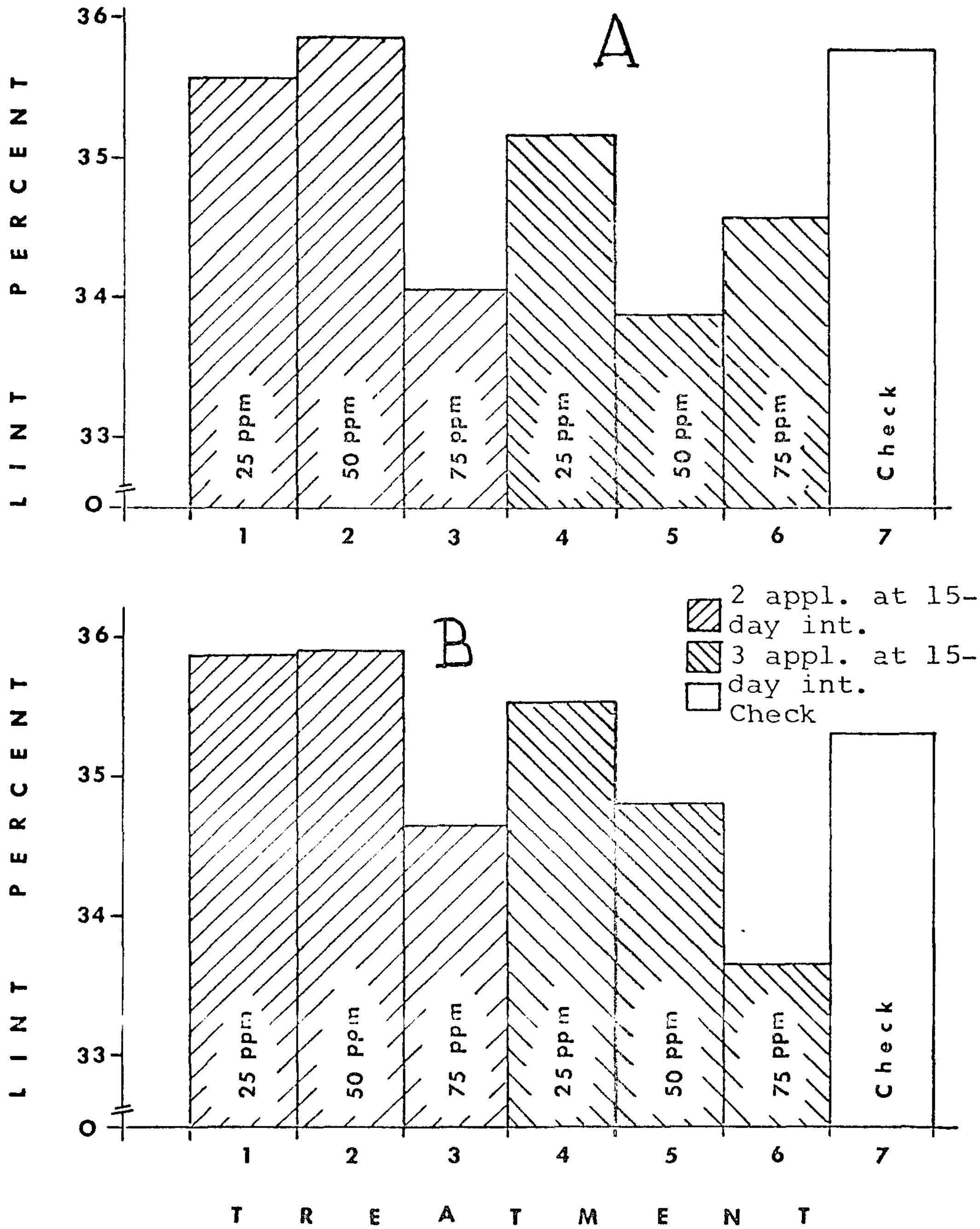


Fig. 11. Lint per cent from the third (A) and sixth (B) harvests of six CCC treatments and the check -- The LSD values at the 5% level at the third and sixth harvests were 1.00 and 0.38 , respectively.

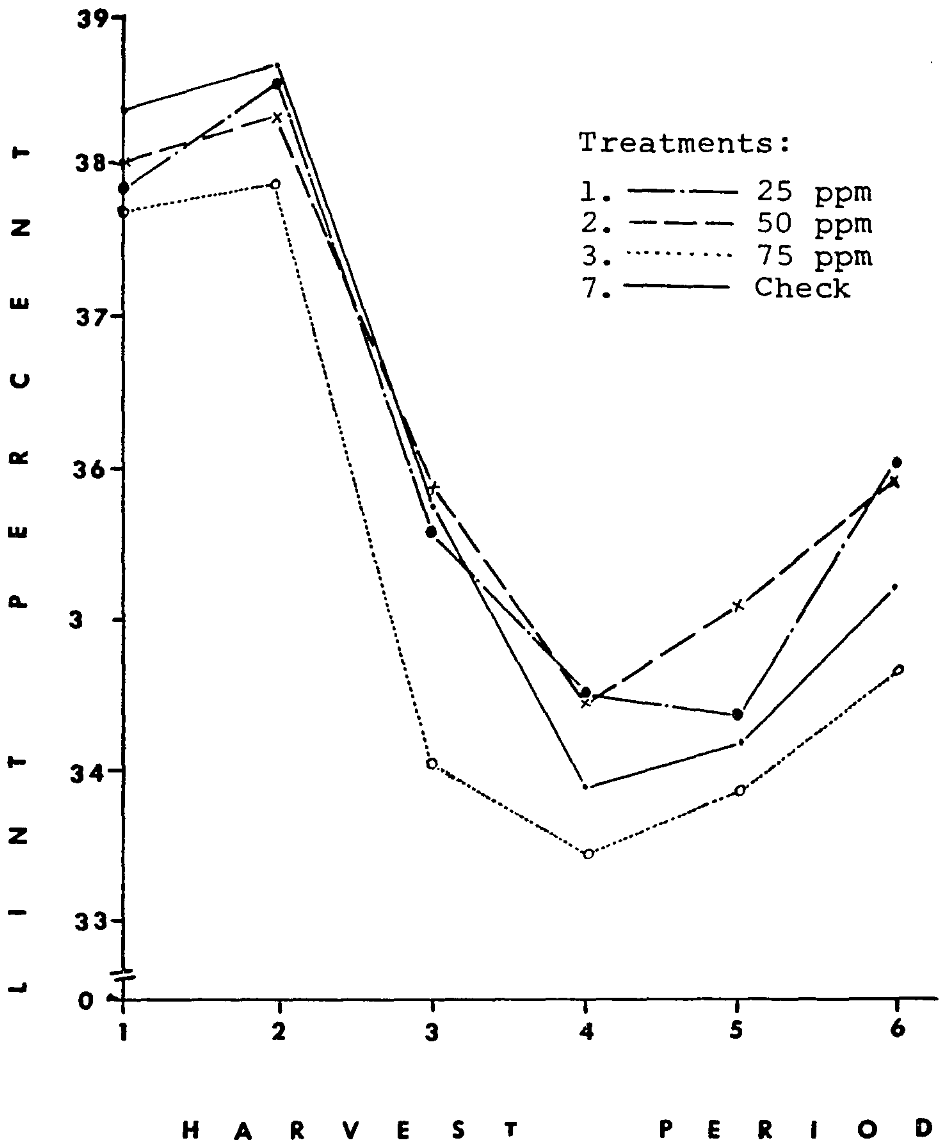


Fig. 12. Lint per cent of three CCC treatments sprayed twice and the check from six harvest periods.

sixth harvests, and Treatment 5 at Harvest 4 (Fig. 13). Three applications of low and medium concentrations of CCC (Fig. 12) reduced lint per cent more than two applications (Fig. 13.).

Lint index values gave statistically significant results only from the sixth harvest. The mean lint index from Harvest 6 from all CCC treatments is shown in Fig. 14. The LSD test indicated that Treatments 1 and 2 were significantly higher than the check, and Treatment 6 was significantly lower. Lint index followed a similar pattern as lint per cent when comparing concentrations and number of applications of CCC. Thus, the highest concentration of CCC sprayed three times reduced lint index more than any other treatment.

To compare the CCC treatments sprayed twice with the check at six harvest periods, the lint index values from Treatments 1, 2, and 3 are plotted in Fig. 15. All treatments gave higher lint index values than the check from all harvests except Treatment 3 at the third harvest. There was a slight increase in lint index from all CCC treatments between Harvests 1 to 2. All CCC treatments and the check showed a continuous reduction in lint index from Harvests 2 to 4, while there was an increase in Harvests 5 to 6.

Lint index values from six harvest periods of CCC Treatments 4, 5, and 6 sprayed three times and the check are shown in Fig. 16. Treatment 4 was similar to the check from

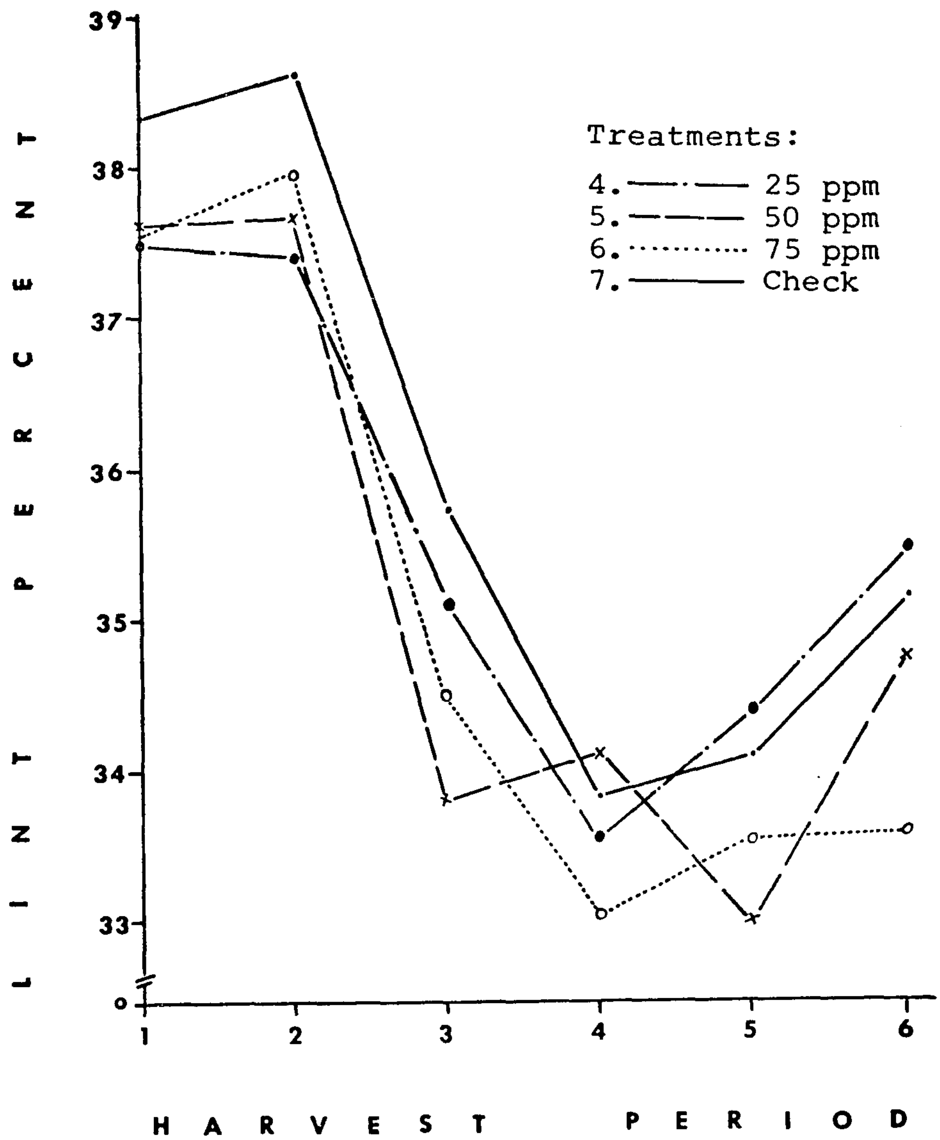


Fig. 13. Lint per cent of three CCC treatments sprayed three times and the check from six harvest periods.

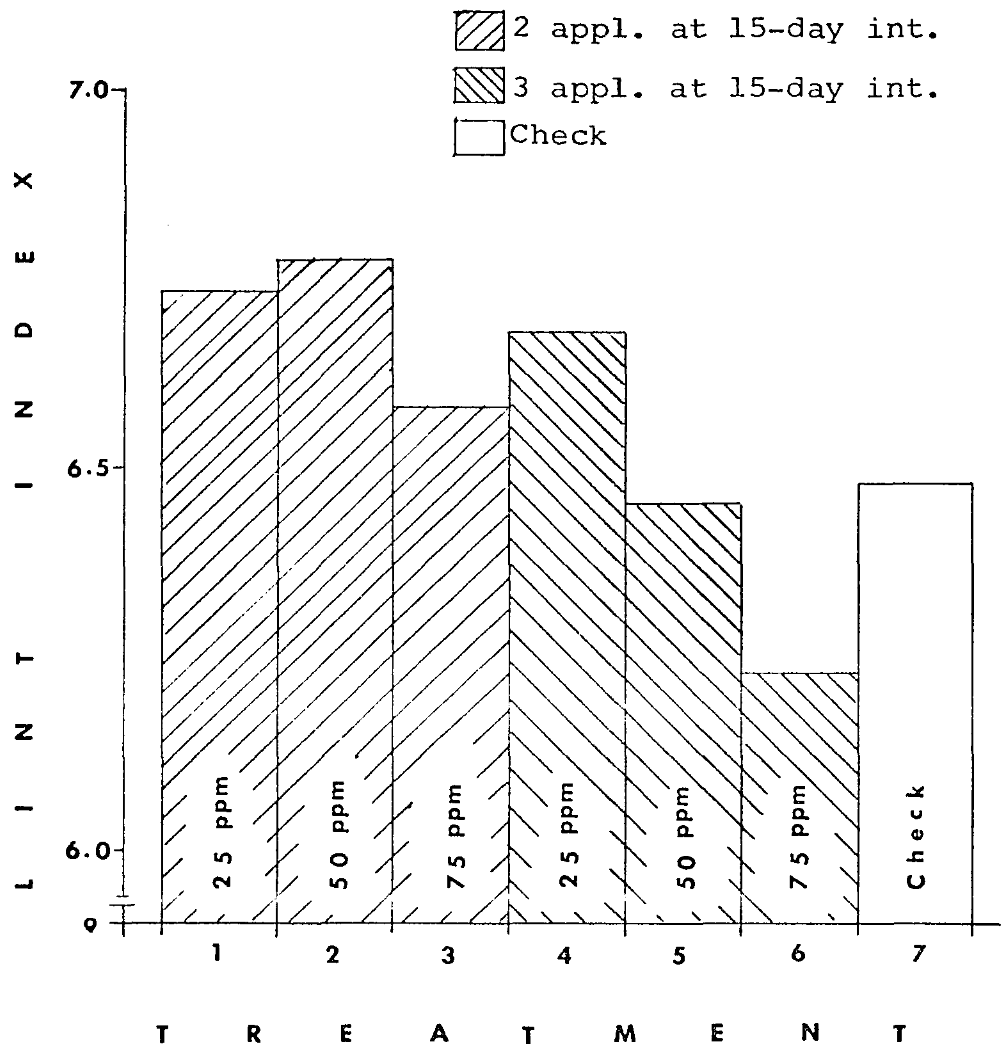


Fig. 14. Mean lint index of six CCC treatments and the check from the sixth harvest period -- The LSD value at the 5% level was 0.26.

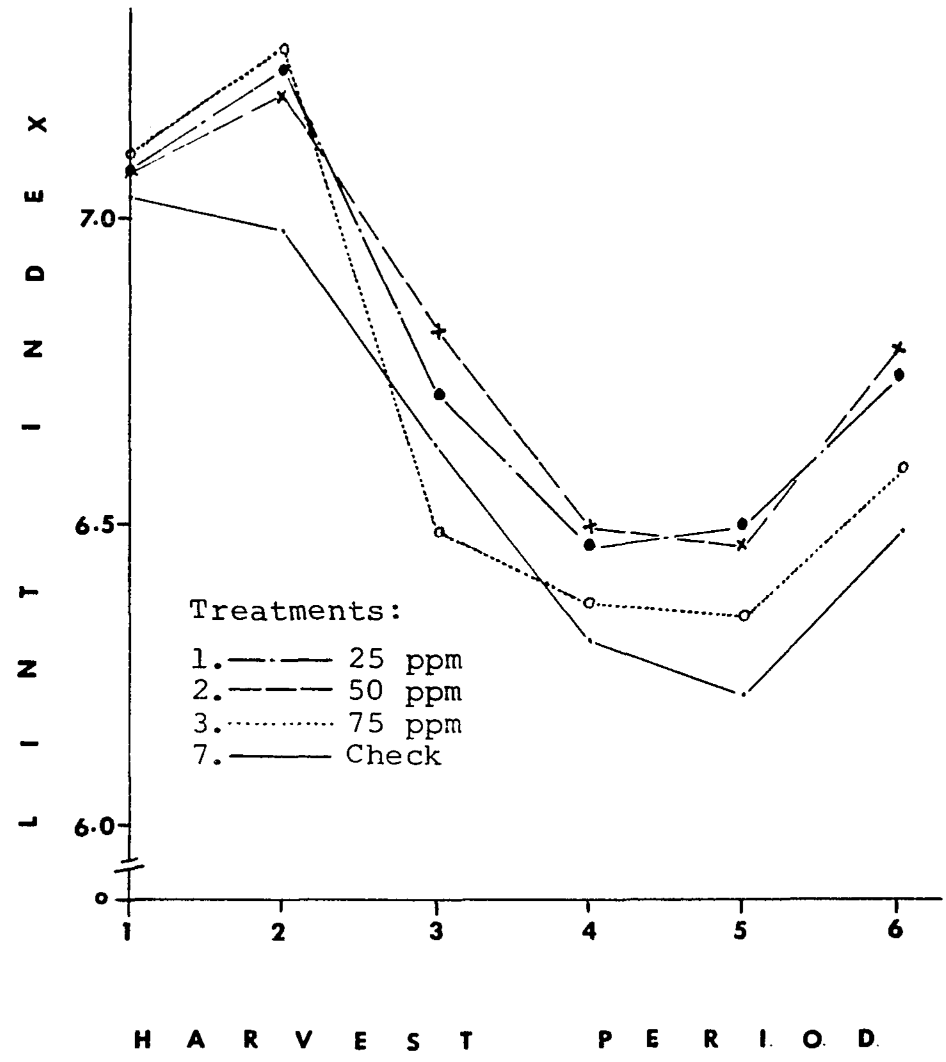


Fig. 15. Lint index of three CCC treatments sprayed twice and the check obtained from six harvest periods.

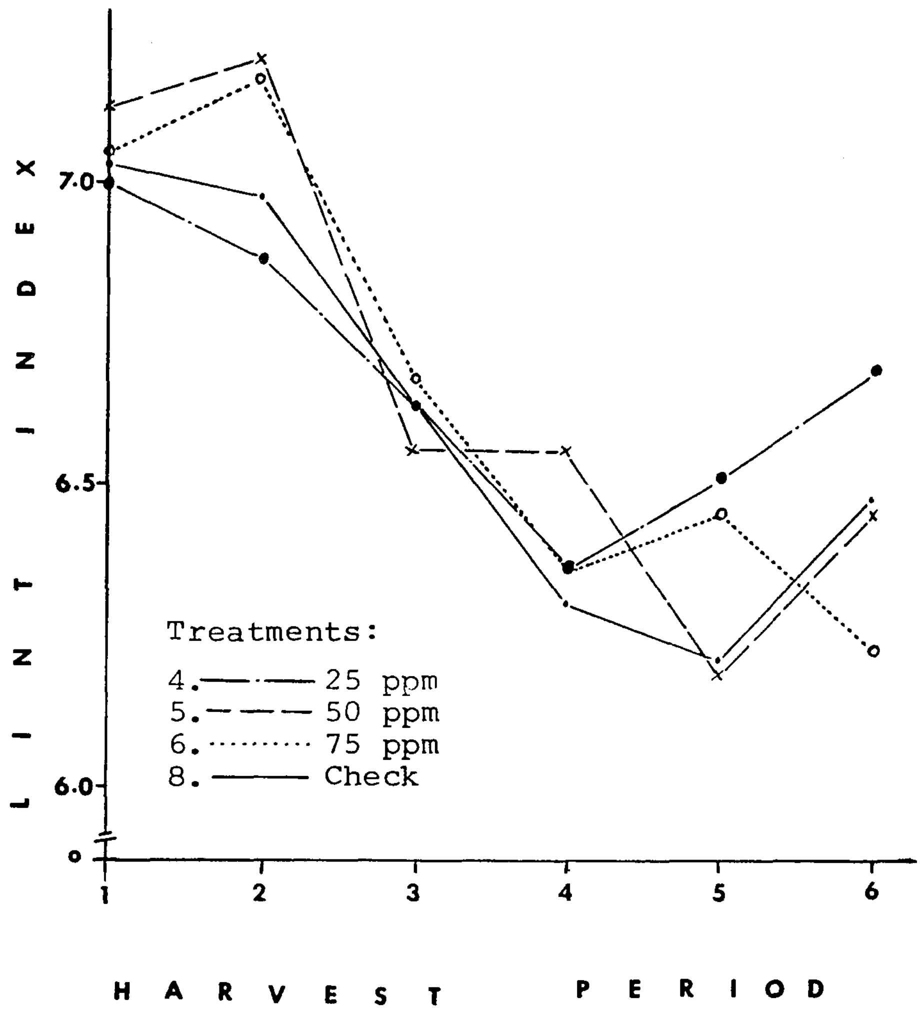


Fig. 16. Lint index of three CCC treatments sprayed three times and the check obtained from six harvest periods.

Harvests 1 to 4 and increased greatly from Harvests 4 to 6. Treatment 5 on the other hand was similar to the check at Harvests 5 and 6. Treatment 6 gave higher values than the check from all harvests except Harvest 6, which was significantly lower.

Data for seed index and fiber length were analyzed and no significant differences were found for any of the six harvest periods. These results differ from those of Bhatt and Nathan (10), who obtained reduced fiber length from treatment of cotton with CCC.

Analyses of variance indicated that fiber strength from CCC treatments was significantly different than the check only from the fifth harvest (Fig. 17). The LSD test indicated that Treatment 1 was significantly lower than the check, and Treatments 3, 4, 5, and 6 were significantly higher than the check. Fiber strength increased as CCC concentration and number of applications increased.

Fiber strength values from six harvest periods of CCC Treatments 1, 2, and 3 sprayed twice and the check are plotted in Fig. 18. All treatments followed a similar pattern as the check over all harvest periods except Treatments 1 and 2 at Harvest 6. All CCC treatments including the check increased in fiber strength successively up to the fourth harvest and were slightly weaker at the last two harvests.

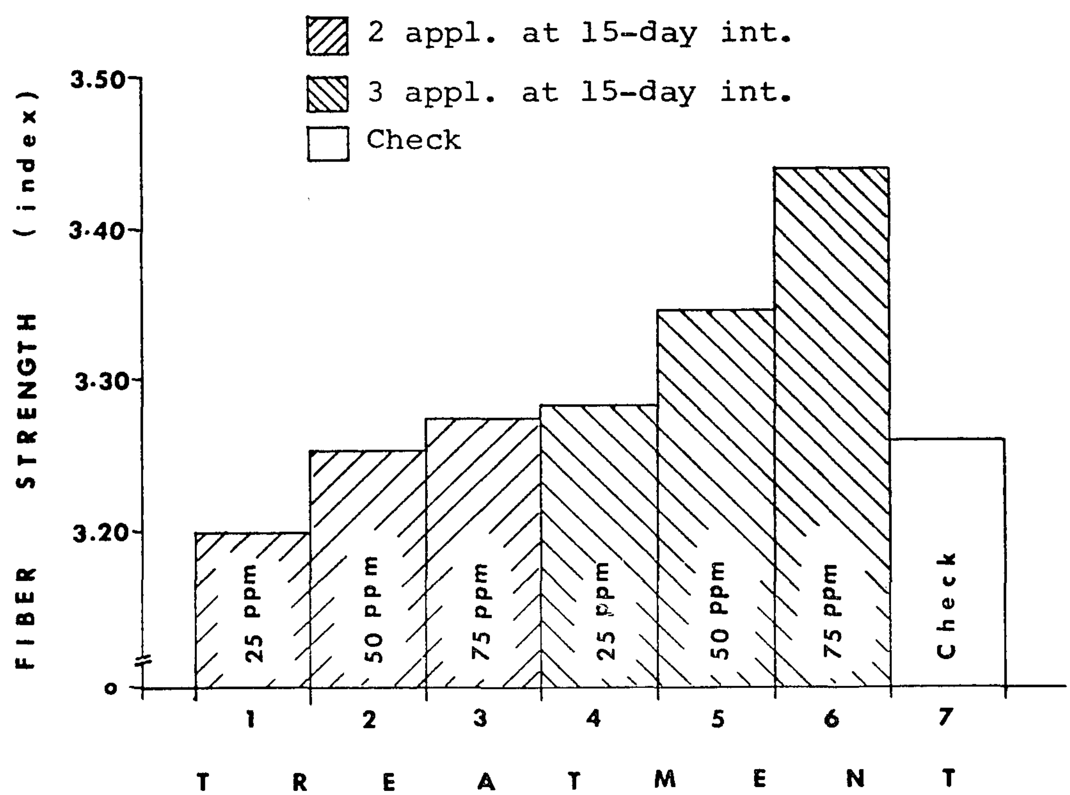


Fig. 17. Fiber strength from six CCC treatments and the check obtained from the fifth harvest -- The LSD value at the 5% level was 0.07.

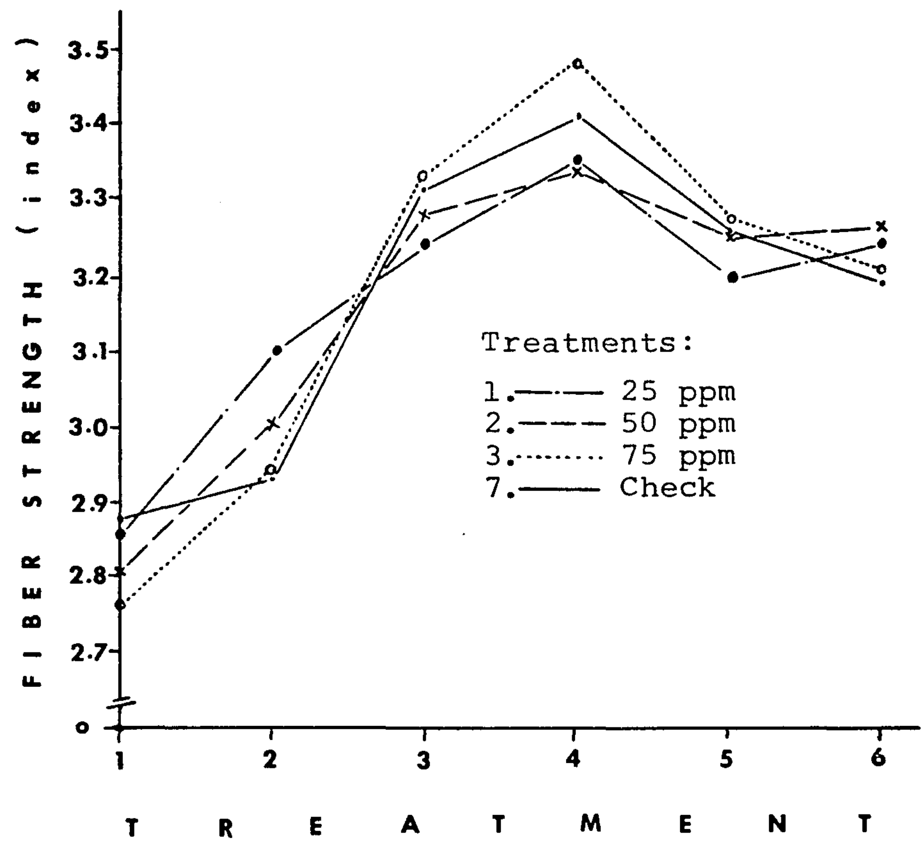


Fig. 18. Fiber strength from three CCC treatments sprayed twice and the check obtained from six harvest periods.

Fiber strength values from six harvest periods of CCC Treatments 4, 5, and 6 sprayed three times and the check are shown in Fig. 19. Treatments 4 and 5 were similar to the check throughout all harvest periods. Treatment 6 gave slightly higher values than the check at all harvest periods; however, they were only significantly higher than the check at Harvest 5.

The highest fiber strength from all CCC treatments and the check was obtained at the fourth harvest. Results indicate that application of high concentration of CCC showed a trend for stronger fiber than the check particularly at mid and late harvests.

Fiber fineness gave statistically significant results only from the first harvest, and is shown in Fig. 20. The LSD test indicated that Treatments 1 and 4 were significantly lower while the rest of the CCC treatments were not significantly different than the check. Increased concentration of CCC sprayed three times showed a positive relationship with increased fiber fineness but it was not observed from the same CCC concentration sprayed twice.

Fiber fineness from six harvest periods of CCC Treatments 1, 2, and 3 sprayed twice and the check is plotted in Fig. 21. Treatment 3 gave slightly lower fineness values than the check at all harvest periods while the other two treatments varied from slightly lower to higher fineness values than the check. All CCC treatments

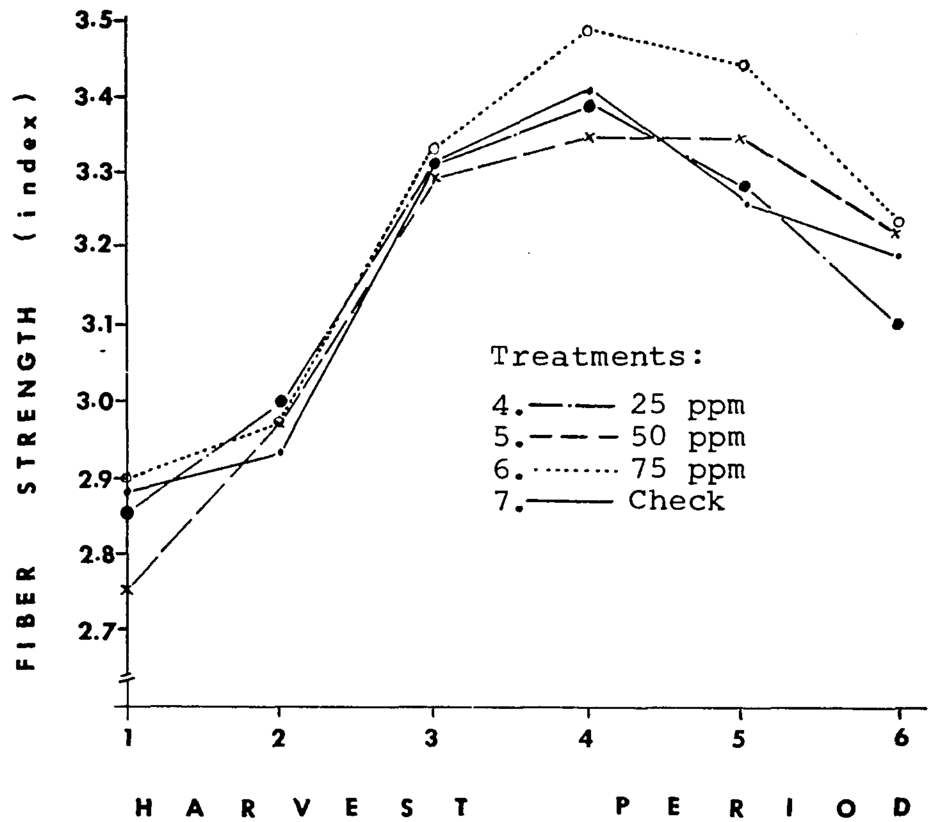


Fig. 19. Fiber strength from three CCC treatments sprayed three times and the check obtained from six harvest periods.

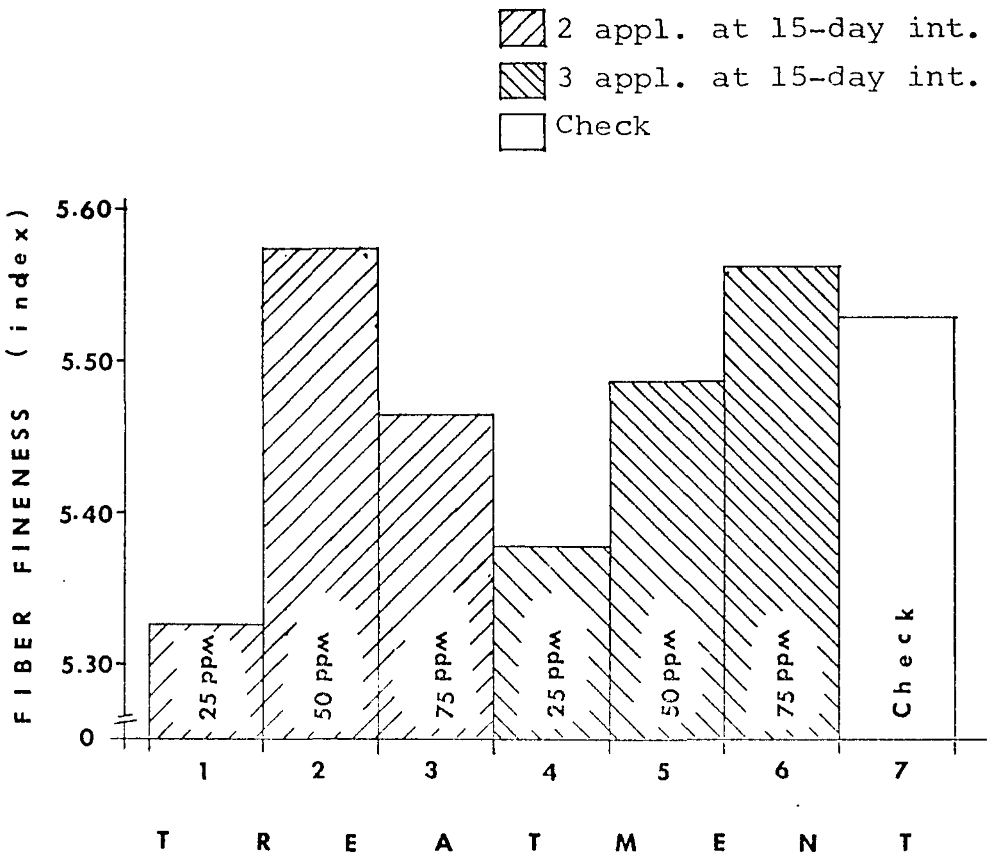


Fig. 20. Fiber fineness from six CCC treatments and the check obtained from the first harvest -- The LSD value at the 5% level was 0.14.

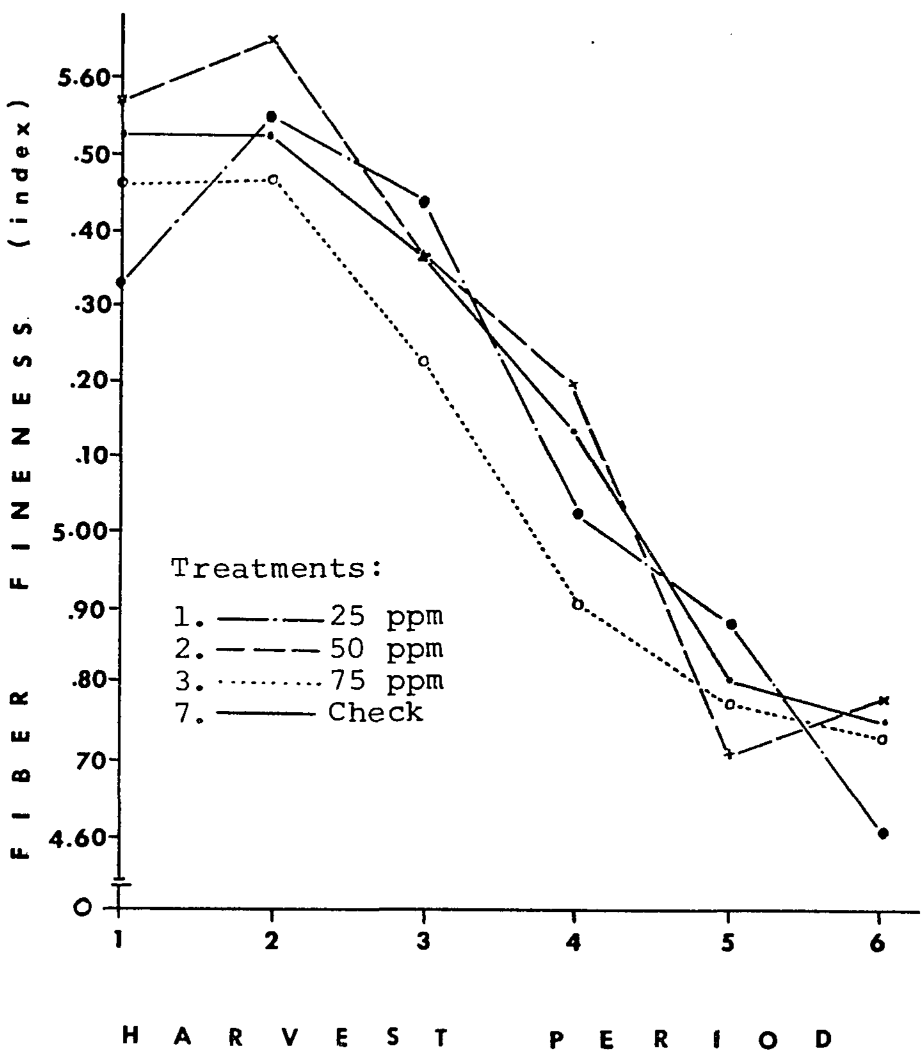


Fig. 21. Fiber fineness of three CCC treatments sprayed twice and the check obtained from six harvest periods.

including the check showed a continued reduction in fiber fineness from the second harvest on with the exception of Treatment 2 which increased from Harvest 5 to 6.

Fiber fineness from six harvest periods of CCC Treatments 4, 5, and 6 sprayed three times and the check is shown in Fig. 22. Again, as with two applications, all CCC treatments including the check showed continued reduction in fiber fineness from the second harvest on with the exception of Treatment 5 which increased from Harvest 5 to 6. Fiber fineness is generally expected to be less from late harvests (5). Results indicate that the lowest concentration of CCC slightly increased fiber fineness at the last two harvest periods while the medium concentration gave a slightly higher fineness value only at the sixth harvest.

Leaf Samples

TIBA

Analyses of variance of data obtained from leaf sampling indicated that there were no significant differences between the leaf size of treated plants and the check. TIBA treatments induced slightly larger leaves than the check 15 days after the last spray of TIBA while the highest concentration slightly reduced leaf size (Table 11). Thirty days after the last application of TIBA, Treatments 2 and 5 produced leaves similar in size to the check while other treatments had slightly smaller leaves.

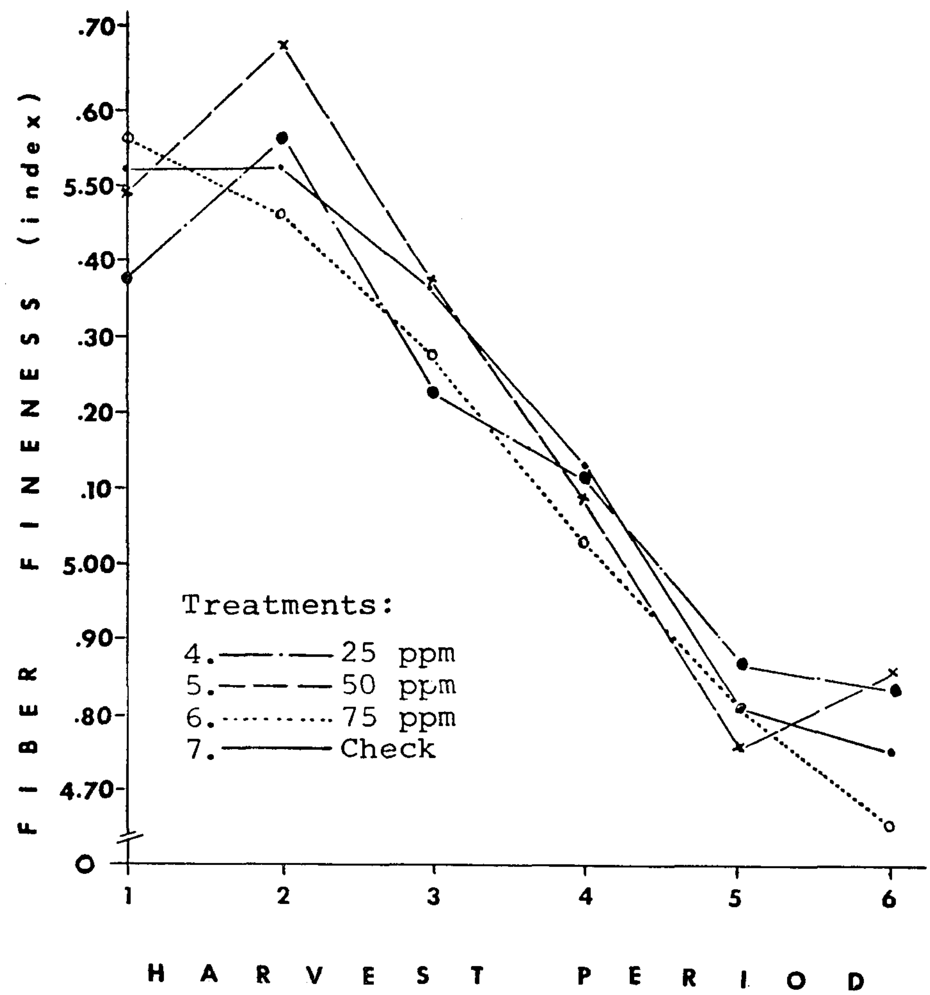


Fig. 22. Fiber fineness of three CCC treatments sprayed three times and the check obtained from six harvest periods.

Table 11. Mean leaf area (sq. cm) of 5 leaves obtained from sampling 15 and 30 days after the last spraying of seven TIBA treatments and the check in 1971.

	TIBA treatments									
	1	2	3	4	5	6	7	8		
	Four appl. 7-day int.			Four appl. 5-day int.			Three appl. 7-day int.			
	Gram TIBA/ha/application									
Days after final spraying	2.47	4.94	9.88	2.47	4.94	9.88	4.94	Check	EMS	F value
15	259.5	252.7	234.5	246.6	257.0	218.8	237.7	242.0	0.042	0.95
30	286.8	318.4	265.7	265.8	319.3	273.9	297.6	320.2	0.080	2.39

Five leaves collected from each plot to determine the leaf dry weight 15 and 30 days after the last spray of TIBA resulted in no significant differences between treatments. The mean leaf dry weight is recorded in Table 12, and shows a similar relationship with the results obtained from leaf area measurements. Low concentrations of TIBA increased leaf dry weight slightly over the check 15 days after the last TIBA application while high concentrations decreased it. All TIBA treatments gave slightly less leaf dry weight than the check from sampling 30 days after the last spray application.

CCC

The mean leaf area measurements from CCC Treatments 1, 2, and 3 sprayed twice and the check are shown in Table 13. Although no significant differences were obtained between treatments, the high concentration of CCC tended to increase the leaf area over the check, while the low and medium concentrations reduced the leaf area of cotton plants 15 days after the last spray. All CCC treatments had slightly lower leaf area than the check when sampled 30 days after the last spray application.

The effect of CCC exists 2 to 3 weeks after treatment. During this period, CCC inhibits plant growth. However, the plant recovers its growth when the effect of CCC disintegrates. During this period, demand for more nutrients

Table 12. Mean leaf dry weight (g) of 5 leaves obtained from sampling 15 and 30 days after the last spraying of seven TIBA treatments and the check.

Days after final spraying	TIBA treatments									
	1	2	3	4	5	6	7	8		
	Four appl. 7-day int.			Four appl. 5-day int.			Three appl. 7-day int.			
	Gram TIBA/A/application									
	2.47	4.94	9.88	2.47	4.94	9.88	4.94	Check	EMS	F value
15	1.89	1.82	1.74	1.79	1.82	1.66	1.79	1.77	0.053	0.80
30	2.02	2.07	1.90	1.95	2.04	1.90	1.72	2.14	0.064	2.15

Table 13. Mean leaf area (sq. cm) of 5 leaves obtained from sampling 15 and 30 days after the last spraying of three CCC treatments and the check (2 sprayings).

Days after final spraying	CCC treatments sprayed twice			Check	EMS	F value
	1	2	3			
	Concentration of CCC (ppm)					
	25	50	75			
15	223.0	222.7	241.3	231.6	403.1	1.83
30	1099.2	965.4	1075.5	1189.4	801.3	2.02

by the plant increases. Therefore, leaf expansion is suppressed by the growing parts of the plant.

Analyses of variance for Treatments 4, 5, and 6 which were treated three times gave no significant differences for the sampling 15 days after the last CCC application (Table 14). However, there was a significant difference for leaves sampled 30 days after the last CCC application. The leaf area from Treatment 6 was significantly lower than the check at the 5% level, while Treatments 4 and 5 gave slightly lower values than the check.

Table 14. Mean leaf area (sq. cm) of 5 leaves obtained from sampling 15 and 30 days after the last spraying of three CCC treatments and the check (3 sprayings).

Days after final spraying	CCC treatments sprayed three times			Check	EMS	F value
	4	5	6			
	Concentration of CCC (ppm)					
	25	50	75			
15	1127.5	1105.7	992.9	1197.8	1021.5	2.03
30	409.5	424.5	383.4	578.3	635.8	2.15

Leaf dry weight from the first three CCC treatments which were sprayed twice, were not significantly different (Table 15). Leaf dry weight was increased slightly over the check by the highest CCC concentration. The medium CCC concentration gave slightly less leaf dry weight than the check 30 days after the last spraying.

Leaf dry weight from Treatments 4, 5, and 6 were not significantly different for leaf samples collected either 15 or 30 days after the last spray (Table 16). Increased CCC concentration indicated a trend toward a positive relationship with increased leaf dry weight. The leaf dry weight from CCC Treatments 4, 5, and 6 obtained 30 days after the last spray were all slightly lower than the check.

Results appear to indicate that the production of leaf dry weight 30 days after the last spray most probably does not depend on the recovery of growth suppression by CCC only. Tables 14 and 15 indicate there was no relationship between leaf dry weight produced 30 days after the last spray and the CCC concentration, nor with the number of applications. Production of dry matter after recovery from the growth suppression by CCC would also be affected by environmental conditions, especially soil moisture.

Table 15. Mean leaf dry weight (g) of 5 leaves obtained from sampling 15 and 30 days after the last spraying of three CCC treatments and the check (2 sprayings).

Days after final spraying	CCC treatments sprayed twice			Check	EMS	F value
	1	2	3			
	Concentration of CCC (ppm)					
	25	30	75			
15	1.73	1.74	2.00	1.70	0.015	1.3
30	2.13	1.90	2.05	2.08	0.020	1.6

Table 16. Mean leaf dry weight (g) of 5 leaves obtained from sampling 15 and 30 days after the last spraying of three CCC treatments and the check (3 sprayings).

Days after final spraying	CCC treatments sprayed three times			Check	EMS	F value
	4	5	6			
	Concentration of CCC (ppm)					
	25	50	75			
15	2.17	2.22	2.27	2.08	0.034	1.3
30	2.02	2.21	2.11	2.34	0.59	2.1

Histological Studies

TIBA

The effect of TIBA on cotton leaves was studied morphologically and histologically.

The significant morphological effect on the external structure of leaves as a result of TIBA treatment was a reduction in leaf area in a reverse relation with increased concentration of TIBA (Fig. 23). This was especially true from observation in 1970 when higher rates were used. The midvein of TIBA treated leaves became larger, and considerable interveinal puckering was observed. Close arrangement of the vascular system was due to the inhibition of laminar expansion which resulted in smaller leaf size with a more toothed edge. Young leaves usually responded faster after TIBA treatment than mature leaves. However, the response of mature leaves to the effect of TIBA was more evident with high concentrations.

Histological examination of treated leaves indicated unusual responses as a result of TIBA treatment, particularly in the arrangement of palisade and spongy parenchyma cells. Treated leaves exhibited considerable intercellular space with thickened cross-sectional area (Fig. 24). Larger intercellular spaces formed between the palisade and spongy parenchyma cells were due to the unusual elongation of palisade cells and inhibition of thickening of the

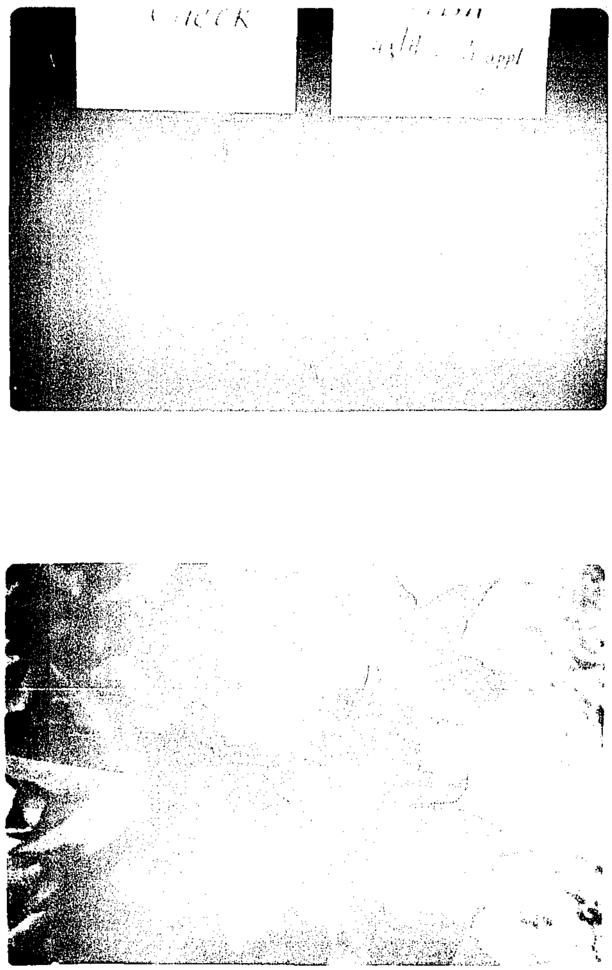
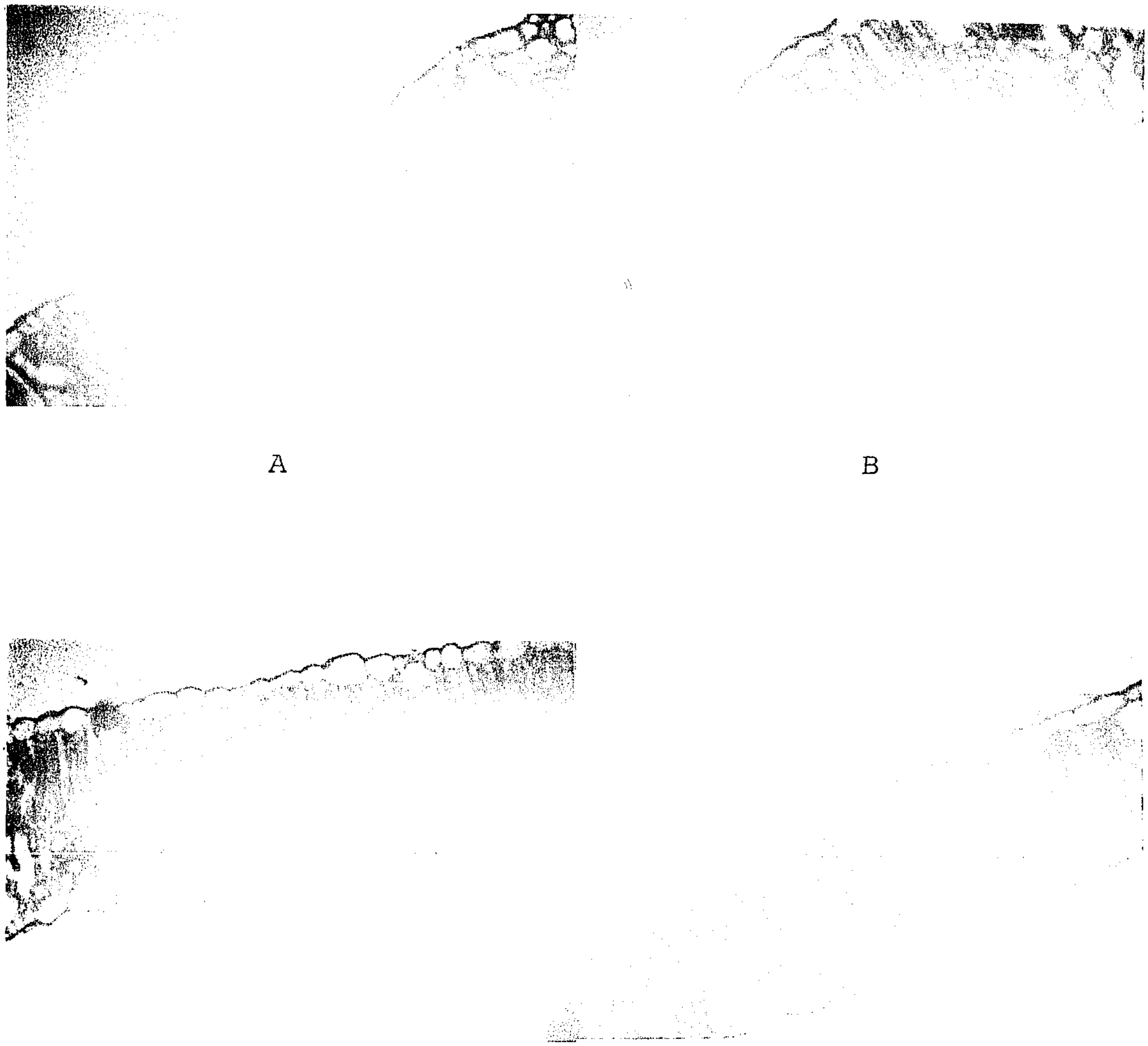


Fig. 23. Effect of TIBA on the reduction of leaf area, formation of toothed leaf edge (top), and interveinal puckering (bottom).



A B

C D

Fig. 24. Cross-section of treated leaves (A, B, C) illustrating the effect of TIBA treatment resulting in unusual elongation and arrangement of palisade cells, larger intercellular spaces, and thickened leaf lamina as compared to the check (D).

parenchyma cells as compared to the check. Hypertrophy in the bundle-sheath of these treated leaves resulted in larger intercellular spaces, most likely caused by the formation of wrinkled lamina in a leathery texture. Figure 24D shows the cross-sectional area of the check leaf with uniformly arranged palisade cells as well as spongy parenchyma which exhibits the normal thickening and elongation within these layers in Upland cotton.

CCC

The effect of CCC on morphological and histological studies indicated that cotton plants showed a different response to CCC than to TIBA treatment. Morphological effects of CCC on cotton were observed as an inhibition of plant growth (Fig. 25). This reduction in plant growth showed a positive relationship with increased concentration of CCC. CCC treated plants became shorter with thicker stems. The dark green color and reduced plant height within CCC treatments is shown in Fig. 25.

In histological studies, CCC treated leaves usually had some development of secondary palisade layers (Fig. 26). The secondary palisade layers were formed in a discontinuous manner with smaller but thicker cells than normal palisade cells.

Regular arrangement of palisade cells as well as characteristic arrangement of spongy parenchyma cells

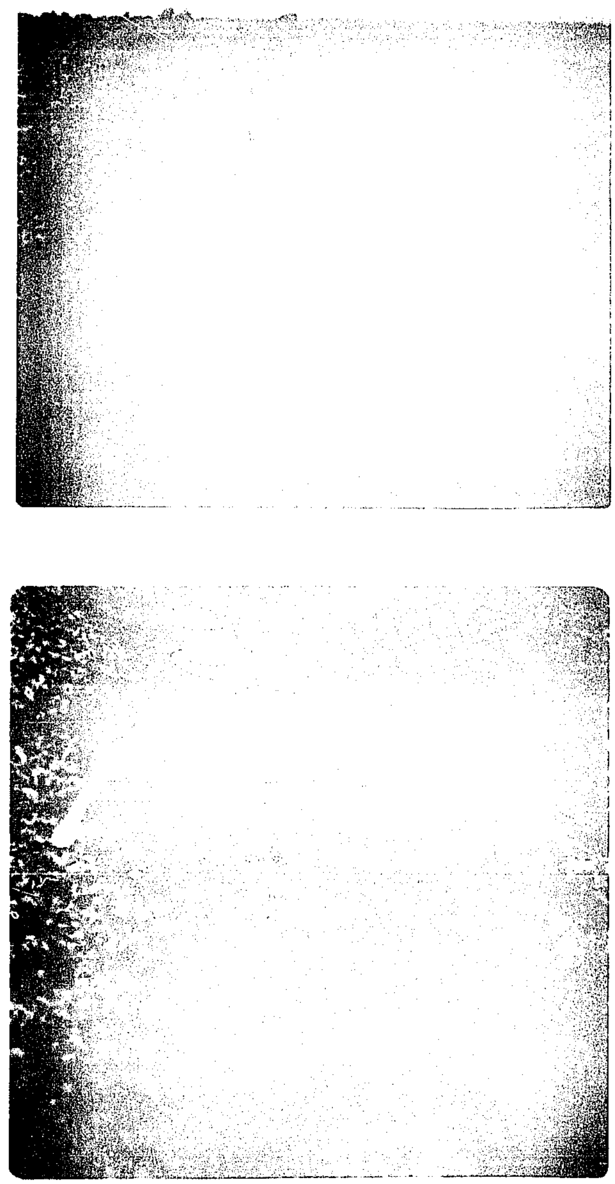
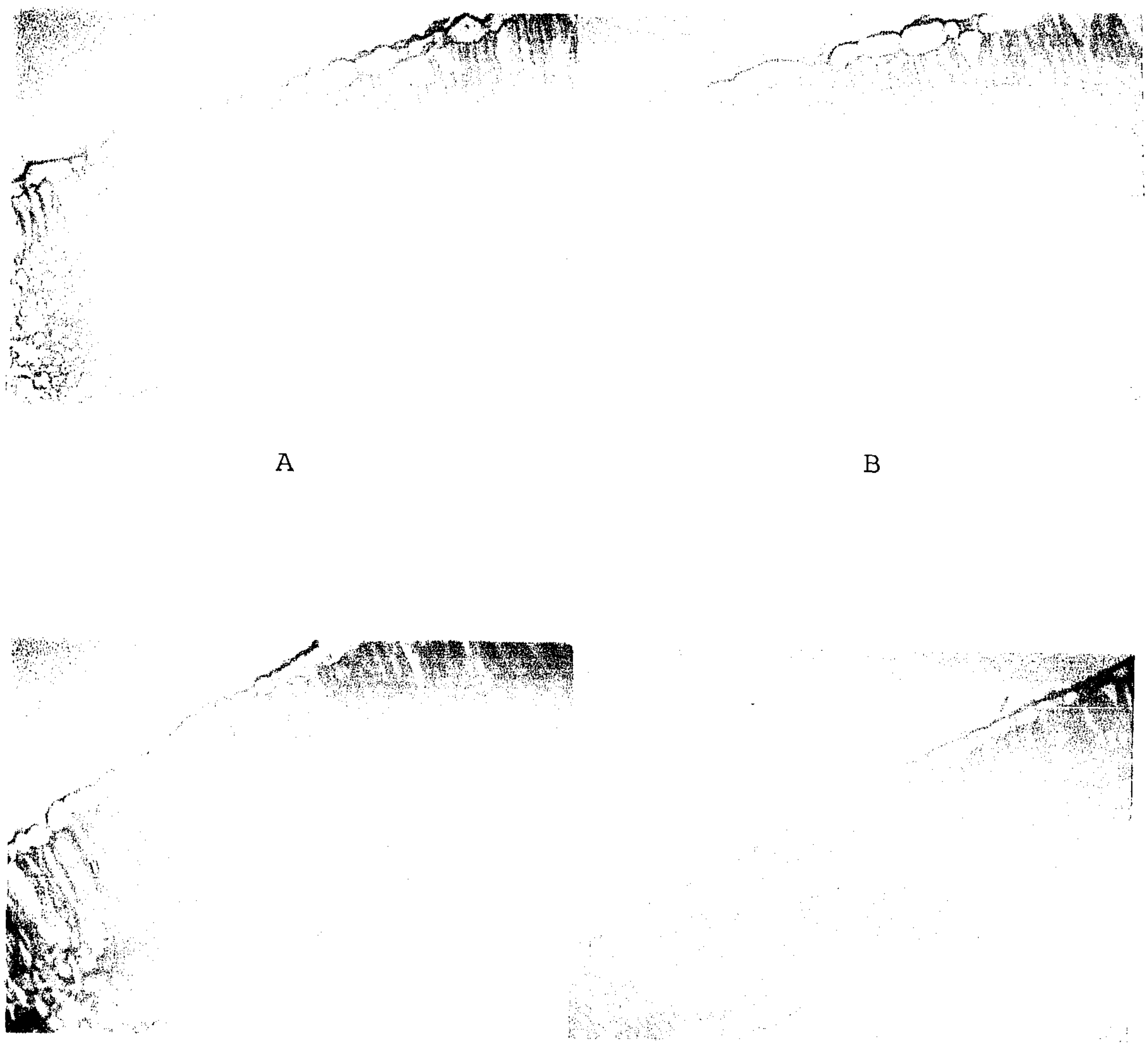


Fig. 25. Characteristic effect of CCC on the inhibition of plant growth and stimulation of dark-green color within the CCC treated plots.



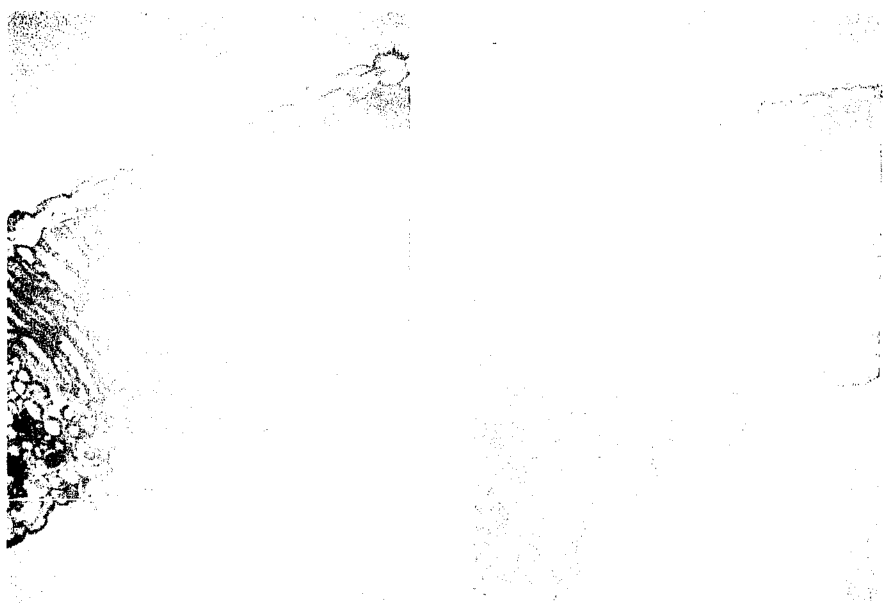
A B

C D

Fig. 26. Effect of CCC on the formation of secondary palisade layers in cotton leaves (A and B) and lower palisade layer (C) as compared to the check (D).

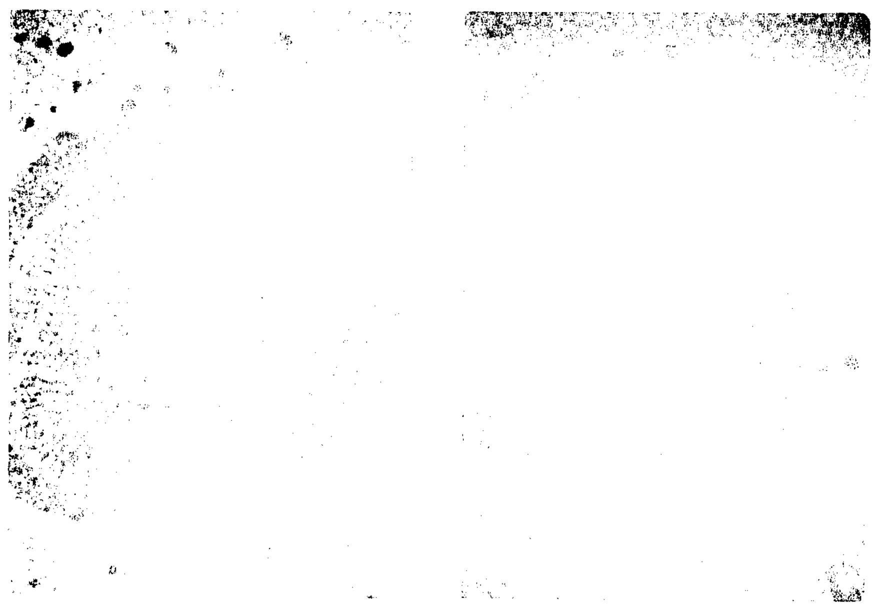
exhibited considerable uniformity in treated leaves. This normal arrangement within palisade and spongy parenchyma was, however, inhibited with increased concentration of CCC as well as leaf age. It was observed in some slides that CCC treatments resulted in the formation of elongated palisade cells with disordered parenchyma cells forming larger intercellular spaces (Fig. 27). In addition, CCC treatments resulted in the formation of lower palisade cells in a discontinuous layer which Upland cotton does not normally have (61, 76). This discontinuous layer contained shorter palisade cells in an irregular arrangement (Fig. 26C). Most of the spongy parenchyma cells having larger intercellular spaces exhibited incomplete differentiation. Leaf thickness was increased due to the formation of the secondary palisade layer which was differentiated into parenchyma cells as the effect of CCC disappeared. Thus, such leaves with single palisade layers exhibited larger spongy parenchyma layers which contributed to the leaf thickness (Fig. 27B).

A cross-sectional area from the leaf petiole showed interveinal puckering in the bundle-sheath (Fig. 28). This puckering in the treated leaf was the result of an increased number of cells in the xylem compared to the phloem.



A B

Fig. 27. Elongated secondary palisade cells (A) which differentiate into parenchyma cells as the effect of CCC disappears (B).



A B

Fig. 28. Effect of CCC on petiole tissues which results in the puckering of xylem cells more than phloem cells which causes greater stem thickness (A) as compared to the check (B).

DISCUSSION

Results obtained from this research indicated that TIBA and CCC had significant effects on plant morphology, anatomy, and physiology of cotton but little effect on yield, fiber, and boll properties.

Results shown in Table 6 indicate that the medium concentration of TIBA resulted in a nonsignificant increase in yield. This agrees with the results obtained by Dastur and Prakash (22), but not with those of Thomas (89) from a TIBA experiment conducted in a greenhouse. On the other hand, yield obtained from high concentrations of TIBA in 1970 (Tables 7 and 8) and in 1971 (Table 6) was always less than the check which agrees with studies by Dastur and Prakash (22). The optimum concentration for increased yield was 4.94 gram active ingredient per hectare per application. Increased concentration over this amount decreased yield while the lowest concentration was similar in yield to the check.

Cotton is an indeterminate plant which flowers and sets bolls over a long period of time. Any chemical or growth regulator which might be effective with another crop would not necessarily give similar results in cotton. Therefore, the response of cotton to growth regulators may require more applications during the growing period for better results. Total yield from the different concentrations of TIBA treatments in this research indicated that the medium concentration sprayed three times at 7-day intervals yielded less than the same concentration sprayed four times at 7-day intervals (Table 6). Results also indicated that the medium concentration of TIBA sprayed four times at 5-day intervals in 1971 increased yield over the check more than the same concentration sprayed four times at 7-day intervals. Hence, shorter periods between applications of moderate concentrations of TIBA would possibly be more effective in increasing yield.

From visual observations early flowering was not induced by TIBA treatments in this study, but peak flowering was earlier than the check. TIBA has been reported by many workers (4, 36, 100, 108) to induce early flowering as well as to increase number of flowers.

Boll formation and development was affected by TIBA treatment without adversely affecting fiber quality. None of the fiber characteristics, including fiber length, strength, and fineness gave significant differences as a result of TIBA treatments.

Generally, fiber length is not significantly changed by environmental conditions. Recent investigations by Murray, Reed, and Oswalt (66) attempting to increase fiber length with fertilizer treatments gave similar negative results to those of Reynold and Killough (74) obtained many years ago. The author did not expect to detect any effect from TIBA treatments on fiber length because TIBA does not act at the DNA level (77) but it is an inhibitor for IAA translocation (3, 49), and may not change the genetical effect since IAA is not effective in increasing fiber length. Studies by Humphrey (43) indicated that fiber length could be altered significantly by hybridization but not by environmental conditions.

Fiber fineness, which may commonly be affected by environmental conditions, did not give any significant differences in this study within any of the harvest periods. These results would be expected since the leaf dry weight and leaf area formation in TIBA treated cotton was not significantly different. The larger the leaf area the more production of organic matter (44).

In this study, lint per cent from the fourth harvest gave significant differences (Figs. 2, 3, and 4). It is difficult to explain why this happened since lint per cent did not show any consistent relation with increased concentration or with the interval of application of TIBA at any other harvest period.

Histological studies indicated that the highest TIBA concentrations had undesirable effects on leaf morphology as well as anatomical structure. Disarrangement of the spongy parenchyma cells, abnormal elongation and distribution of the palisade cells resulting in the formation of larger intercellular spaces indicate that the differentiation in the leaf tissues was greatly affected by TIBA (Fig. 24). Histological studies made by Ghorashy, Colville, and Ashworth (33) on soybean leaves indicated a close arrangement of palisade, particularly mesophyll cells due to the reduction in leaf area and hypertrophy in the bundle-sheath. Histological studies in their research also indicated that TIBA was more effective on young cotton leaves than on older leaves (57). This characteristic showed a close relationship with increased TIBA concentration.

Dry matter production in the leaf was slightly increased by low and medium concentrations of TIBA 15 days after the last spray application (Table 12). However, 30 days after the last TIBA spray, dry weight was reduced. This is in agreement with the research of Krause (56) and Krause and Boke (57). According to Krause, the reduction in dry matter of soybean leaves followed a basipetal direction 30 days after application. This reduction was most likely due to the increased meristematic activity 2 to 3 weeks after TIBA treatment, during which time the plant recovers its growth.

TIBA increased the leaf area slightly with low and medium concentrations (Table 11). However, the highest concentration indicated a reduction in leaf area. The stimulatory effect of low TIBA concentration was now, however, observed in the leaf sampling 30 days after the last TIBA application (Table 11). There is insufficient information about the effect of TIBA on leaf development. If TIBA inhibits cell division on the marginal meristem, the palisade and spongy cells should not show any intercellular space after cell thickening starts. If TIBA exerts its effect on leaves during the primordial stage it would not be effective on fully expanded or mature leaves. Sunderland (86) reported that TIBA was probably effective on the marginal meristem. Wardlaw (98) did not agree and cited that TIBA exerted its effect during the initiation of leaf primordia and midvein formation as well as during the laminal development. Results obtained from this study from two samplings of fully expanded leaves indicated that TIBA probably exerted its effect not only during the primordial stage but during leaf extension as well.

Results obtained from this study in 1971 indicated that the low concentration of CCC resulted in a slight but nonsignificant increase in yield. All treatments in Harvest 2 resulted in more seed cotton than the check. The low concentration of CCC applied twice in 1970 and 1971 always gave more seed cotton than the check, but not high concentrations (Tables 9 and 10). However, there was no marked yield increase over the check from low CCC concentrations sprayed only once in 1970 (Table 10), or three times in 1971 (Table 9). Yield reduction was associated with increased concentration and number of CCC applications.

This reduction in yield potential was apparently due to the inhibitory effect of CCC on plant growth. Thus, the cotton plant became smaller with shorter fruiting branches having less flowers than the check. Singh (81) and Singh and Singh (80) also came to the conclusion that low CCC concentrations increased seed cotton yield under field conditions while high concentrations significantly decreased it. However, an experiment by Zur et al. (110) resulted in low yield due to late maturity. Late application of low CCC concentration in this study gave slightly increased yield over the check but not the high concentration (Table 10). Late application of CCC reduced wheat yield according to Bokhari and Youngner (11), but not according to Rudich et al. (75).

First flower was delayed by CCC only 1 day compared with the check, but boll opening was delayed 3 to 4 days. Similar results were obtained by Thomas (89). However, Bhatt and Nathan (10) concluded that flower initiation was not shifted by CCC treatments, but boll opening was delayed resulting in lower yield due to less boll set. Reduction in flowering in cotton by CCC treatment was attributed by De Silva (24) to the reduced number of fruiting branches, and by Thomas (88) to the inhibition of growth of sympodial branches. On the other hand, increased flowering in wheat was the result of tillering and formation of new spikes (45, 50). In addition to the effects of growth regulators on flowering, the rate of flower fertilization from the CCC and TIBA treatments was studied by determining unfertilized carpels of the bolls in 1970. Neither of the growth regulators had a significant effect on flower fertilization.

Boll weight from the second and sixth harvest periods in this study gave significant differences from the check. Almost all CCC treatments gave larger bolls from the last three harvests (Figs. 9 and 10). This is in agreement with the results of Singh and Singh (80). CCC treated plants remain green during the late period of the growing season which allows better boll development resulting in increased weight per boll. Fiber development showed slightly increased fiber fineness from the late harvest over the check, but larger seed development was more significant than fiber maturity. CCC treatment of potatoes resulted in increased tuber weight due to a longer maturation period (25).

Lint per cent from the third and sixth harvest periods in this study was significantly different than the check (Figs. 11, 12, and 13) which does not agree with the results of Singh and Singh (80), and Zur, Marani, and Karadavid (111). Low and medium concentrations of CCC sprayed twice gave slightly higher lint per cent from the late harvests while the higher concentration always gave less lint per cent than the check (Fig. 12). The highest concentration sprayed three times also gave less lint per cent than the check, particularly at Harvest 6 which was significantly lower (Fig. 13). Lint per cent and fiber fineness from late harvests is generally expected to be less than at early harvests (5). However, highest CCC concentration showed a trend to reduce lint per cent at late harvesting compared to the check (Figs. 12 and 13).

Fiber length was not significantly affected by CCC treatments. However, fiber length was slightly increased from CCC treatments in a positive relationship with increased concentration and number of applications. This increase might have been expected because water stress which occurred within the plots most likely did not reduce fiber length due to the effect of increased drought resistance by CCC treatments visually observed in this study. Since fiber length is primarily under genetic control, only irrigation or rainfall have much effects in modifying it (43, 74).

Fiber strength was significantly effected only in the fifth harvest (Fig. 17). However, the highest CCC concentration applied three times caused a nonsignificant increase in fiber strength over the check (Figs. 18 and 19).

Bollworm (Heliothis zea B.) incident within the CCC treated plants was higher than the check treatment. Singh and Singh (80) observed that CCC treatment reduced bollworm incidence in cotton. It is the author's opinion that the severe bollworm incident observed in this study was due to the attraction of the bollworm moths to the green plants and succulent bolls maturing over a longer period than the check.

Some of the most interesting results of CCC treatment observed in plant morphology was the inhibition of plant growth, reduction in length and number of branches, but slightly thicker stem and dark-green-leaf color particularly with increased concentrations and number of applications of CCC (Fig. 25). This is in agreement with the results obtained by many workers (10, 24, 26, 80, 82, 88, 89, 110, 111). Parkash (71) also reported that CCC caused shorter stems, dark-green color, and thickened leaves, and a smaller leaf area which increased dry weight. According to Parkash and Lal (72), reduction in leaf area has been observed only in the lower part of CCC treated cotton plants. The larger leaf area in the upper leaves might be due to the stimulatory effect of increased level of nutrients resulting from the inhibition of translocation in the upper leaves compared to the lower leaves. Nitrate accumulation in the treated cotton leaves was observed by Singh (82) to stimulate the normal growth of the leaf. Leaf area in this study was increased with high concentrations of CCC sprayed twice (Table 13) but not with high concentrations of CCC sprayed three times (Table 14). With more applications, leaf area was reduced as the CCC concentration increased. This agrees with the results obtained by Dyson (25), and Humphries (44).

Leaf dry weight increased over the check by increased concentration as well as by increased number of applications of CCC (Tables 15 and 16). This increased dry weight probably was the result of less demand for food by growing tissues where growth was inhibited. It also seems possible that increased number of palisade cells after the formation of a secondary palisade layer may contribute to the photosynthetic activity resulting in more organic matter production. Humphries (45) found that CCC delayed protein hydrolyses resulting in increased dry weight.

The most interesting results of CCC treatment were observed from the histological studies. Upland cotton normally has only one upper palisade layer and no secondary or lower palisade layers (61, 76) while Asiatic type cottons have upper and lower palisade layers. Microscopic examination of leaf sections showed an incomplete secondary as well as lower palisade layers (Fig. 26). CCC is a GA antagonist (38, 67), but it was also reported by Kuraishi and Muir (58) that CCC does not have an antigibberellin effect. If CCC acts at the nucleic acid level resulting in increased IAA oxidase activity (32) cell division in the leaf will not increase due to less auxin and GA concentration. However, the palisade layer as well as spongy parenchyma layer showed normal cell number and arrangement (Fig. 26). Therefore, formation of secondary and lower palisade cells in a discontinuous partial layer might indicate that CCC was more effective on the physiological condition which controlled cell differentiation in the leaf. Microscopic slides prepared from leaves obtained 30 days after the last application of CCC did not show lower and secondary palisade layers clearly. They were almost differentiated to parenchyma cells.

CCC exerts its effect 2 to 3 weeks after application. It seems possible that 30 days after the final application of low rates of CCC, the plant recovers its normal growth (which was observed in the field in this study) and continues as the check plant.

Formation of an incomplete secondary palisade layer may accelerate the photosynthetic process resulting in more carbohydrate production, which might increase the amount of nitrate nitrogen and protein nitrogen.

SUMMARY AND CONCLUSIONS

Field and laboratory studies were conducted to investigate the effect of the growth regulators, TIBA and CCC, on yield, boll and fiber characteristics, morphology, and anatomy of cotton plants.

Results indicated that the most effective concentration of TIBA and interval between applications for yield increase was a medium concentration (4.94/ha) applied at 5-day intervals for four applications.

Statistical analyses showed that TIBA was effective in increasing lint per cent significantly only at the fourth harvest period. Results also indicate that the highest TIBA concentration applied at 5- or 7-day intervals gave more lint per cent from early and late harvest periods.

Concentration and interval of application of TIBA did not have any significant effects on seed index and fiber characteristics obtained from the different harvests.

High concentrations of TIBA had undesirable effects on plant morphology, particularly on the leaf, as well as on yield. Reduction in leaf area and curling of leaf lamina occurred with increased TIBA. However, low and medium concentrations gave a nonsignificant increase in leaf area. Leaf dry matter was increased by low and medium concentrations of TIBA 15 days after treatment, but not significantly.

Reduction in leaf area and leaf dry weight 30 days after treatment did not show any relation with concentration and number of applications of TIBA.

Plant height was suppressed with increased concentration and number of applications of TIBA.

Histological studies indicated that TIBA inhibited differentiation of tissues in the leaf, specifically the orientation and thickening of palisade and spongy parenchyma cells.

Total yield was nonsignificantly increased from the low concentration of CCC treatment sprayed twice than any other treatment or the check. Increased CCC concentration and number of applications resulted in further yield reduction. Late application of CCC also reduced yield.

Fiber and lint characteristics of cotton were affected by CCC more than by TIBA. Boll weight was increased by CCC treatments. A trend was observed between increased concentrations of CCC and increased boll weight. However, increased number of applications showed positive correlation with increased boll weight only with low and medium concentrations. Increased number of applications of the highest concentration did not stimulate boll weight as much as high concentrations of CCC applied twice.

The medium concentration of CCC applied twice gave slightly higher values from mid and late harvests than any other treatment or the check.

Lint index from the last harvest of CCC treatments sprayed twice was significantly higher than the check while only the low concentration sprayed three times was significant. The medium concentration of CCC applied twice gave higher lint index values than any other treatment or the check.

Seed index values obtained from different harvest periods were not significantly different. However, all treatments had slightly higher seed index values than the check. Increased seed index values showed positive correlation with increased concentration and number of applications of CCC. The average seed index value obtained at the end of the harvest season from the highest concentration of CCC applied twice and three times was more than any of the other treatments or the check.

Fiber length was not significantly affected by CCC and it showed no relationship with the amount and number of applications of CCC.

Fiber strength was increased by CCC treatments during the late part of the season. Significantly increased fiber strength values were obtained from the fifth harvest only. Fiber strength showed a negative relation with increased concentration of CCC and with the number of CCC applications.

No relationship was observed between fiber fineness and the CCC concentration, or with the number of applications of CCC. However, the medium concentration of CCC sprayed twice gave slightly higher mean fiber fineness than any other treatment or the check.

CCC had a definite effect on plant morphology. It reduced plant height, leaf area, and the length of branches. However, it increased stem thickness and stimulated the formation of dark-green leaf color.

Leaf area was reduced nonsignificantly by CCC treatment. This reduction was slightly more with increased concentration and number of applications of CCC.

Leaf dry weight was also increased nonsignificantly by increased CCC concentration and number of applications. Reduction in dry weight 15 and 30 days after CCC treatments did not show any relation with increased concentration and number of CCC applications.

Histological studies suggested that CCC treatment inhibited differentiation of cells into spongy mesophyll. Incomplete secondary and/or lower palisade layers were observed in CCC treated leaves.

Results within the limits of this investigation suggest that significant yield increases may not be obtained from cotton treated with TIBA. Fiber properties can be expected not to be significantly altered by TIBA treatment.

Results also suggest that CCC treatments may not significantly increase cotton yield but fiber properties might be affected. However, these limited data need further verification for better justification.

Due to the suppression of plant growth, TIBA and particularly CCC may contribute to the narrow-row planting system where full irrigation and proper amount of fertilizer are used. These regulators inhibit excessive growth of cotton plants, resulting in slightly thicker stem formation, which may contribute to the plant being more erect and help reduce any lodging problem to a certain degree. Late application of CCC to cotton plants can inhibit excessive plant growth which may increase harvesting efficiency.

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