THE EFFECTS OF VARIOUS NUMBER OF APPLICATIONS AND TREATMENTS OF GROWTH RETARDANTS ON LEAF FORMATION, BOLTING, AND YIELD OF LEAF AND COS LETTUCE (LACTUCA SATIVA L.)

By

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CHAPTER I

INTRODUCTION

In many vegetables, the development of seed stalks destroys the value of market crops. In the lettuce plant, seed stalk formation, commonly called bolting, is very difficult to control because of unfavorable temperatures in many production areas. Maximum production of high quality lettuce plants cannot be achieved when the temperatures are high (70° to 80°F) and daylengths are long (10 to 16 hours) (5, 32, 33). In Oklahoma these conditions are frequently prevalent from May to September, resulting in the prevention of quality lettuce production. Prior research with growth retardants to lettuce has been limited mostly to this influence on bolting. The inhibition of flowering as a result of growth retardants application has been reported by many researchers (2, 17, 26) and found that growth retardants could delay bolting at various concentrations and stages of plant growth.

The object of this study was to investigate the effect of various number of applications and concentrations of two growth retardants, CCC (2-chloroethyl trimethylammonium chloride) and Alar (succinamic acid 2, 2-dimethyl hydrazide) on plant growth and development of leaf and cos lettuce and determine their effect to delay bolting under different growing seasons.

CHAPTER II

LITERATURE REVIEW

There have been many reports associated with the effect of growth retardants on the inhibition of seed stalk initiation in lettuce plant under greenhouse and field conditions. These growth retardants have been reported effective in retarding plant growth in a wide range of genera and species.

Gibberellin-like Responses

The bolting of lettuce plants are characterized by the rapid elongation of internodes. The leaves are more narrow, slightly longer, and paler green in color. These symptoms are also typical of various genera and species of plant treated with gibberellic acid (4, 20).

Bukovac and Wittwer (5) found that when the reproductive responses of Great Lakes cultivars of head lettuce which had been seed vernalized were compared to lettuce plants which had been treated with gibberellic acid, the vernalized plants were similar to the gibberellic treated plants with respect to internodal elongation, leaf size, and color. This investigation suggests that the naturally occurring process of bolting induced by treating lettuce plant with gibberellic acid. These experiments have led some researchers to conclude that seed stalk development in lettuce is a gibberellin-like response that may actually be caused by an assimilation of gibberellic acid in the plant.

Causes of Bolting

The physiological responses of plants to gibberellic acid are of an essential nature. Such changes as internodal extension and induction of flowering take place naturally in suitable environmental condition (3). Premature seed stalk formation of lettuce plant or bolting may be induced by various combination of temperature and photoperiod (42). Raleigh (30) reported that the day temperature could be in a higher range (70° to 80°F) without undue seed stalk elongation if the night temperature was cool (50°F). Rappaport and Wittwer (33) found that in head lettuce cultivar Great Lakes, night temperatures above 65°F subsequent to seed vernalization accelerated flowering and resulted in seed stalks without preceding head formation. A combination of high temperatures and long days will promote flowering in seedlings vernalized in excess of 13 days at 40°F.

Mechanism of Foliar Penetration

Overbeek (27) suggests that waxy unbroken cuticles of a mature leaf are very difficult to penetrate. Both organic and inorganic material either did not penetrate or penetrated very slowly. It would seem then that the thick cuticle of mature leaves is an unlikely site for the penetration of chemical applied in sprays. Skoss (40) reported that stomates act as the major portal of entry, regardless of the nature of the sprayed substance.

Up to the present time, however, the passage through stomatal pores has only the effect that the solutions enter cavities such as stomatal chambers and intercellular spaces but not the cells themselves. The outer walls of cells lining these cavities are also covered by an internal cuticle. Such stomatal penetration would be of some advantage because the absorbing surface is enlarged, the internal cuticle within the cavities, may be thinner and more easily penetrated (1).

Pall (28) reported that increasing temperature within physiological limitations have resulted in increased penetration. Increased absorption at a higher humidity was correlated with degree of stomatal opening.

Mode of Action of Growth Retardants

Sachs et al. (36) found that the subapical meristematic activity plays an important role in stem development of plants and the apical meristem is the site of shoot or leaf formation. As a result of treatment with growth retardants the stems were shorter because of the principal effect of growth retardants upon the inhibition of cell division and elongation of the subapical meristem.

There have been at least three possible modes of action proposed for the short internode resulting from the treatment of growth retardants.

The first theory is that growth retardants may cause inhibitions which are not directly related to either GA or auxin metabolism. Sachs and Wohlers (37) have shown that the inhibiting effect of retardants on carrot callus growth is not reversed by either GA or auxin. Likewise, the effect of CCC and Phosfon-D on leaf growth of Raphus sativa L. var. acanthiformis Makino (Riso-daikon) was not reversed by either GA or auxin (18).

A second possibility is that growth retardants block the synthesis of GA and decrease the production of this hormone. The ability of CCC and Amo-1618 to prevent GA synthesis in Fusarium moniliforme has been shown by Harada and Lang (16) and Ninnemann et al. (24). Zeevaart and Lang (44) found that same effect of growth retardant in Bryophyllum-daigremontianum. The results of such a mode of action could be that growth retardants become competitive inhibitors of endogenous growth hormones. The inhibition of gibberellin synthesis would be reversable if more gibberellic acid was added (45). The inhibition of gibberellin synthesis has been suggested by many researchers (10, 29, 35, 43).

A third possibility is that growth retardants may affect some aspect of the auxin metabolism of the tissue (25, 31, 34, 35). Halvey (15) reported that gibberellic acid inhibited and growth retardants stimulated the activity of peroxidase and indole acid oxidase, both responsible for destruction of IAA. Karaishi and Muir (18) found that the inhibitory effect of CCC on Avena coleoptile growth was overcome by higher concentrations of IAA but not by gibberellin.

Methods of Application

Growth retardants have been applied as a foliar sprays and soil drenches (particularly suitable for container grown plants). Sachs and Hackett (39) reported that SADH and ancymidol can be foliar applied at a level inhibiting stem elongation without causing foliar injury. Other growth retardants such as chlormequat or Phosfon usually cause some distortion, and/or inhibition of apical meristematic activity at concentrations required for inhibition of stem elongation. Phosfon is most often used as a soil drench on pot plants whereas SADH is used as a foliar spray and ancymidol either as a soil drench or foliar spray. Cathey et al. (8) found that B-Nine was effective as a foliar application for producing compact plants at any daylength for a wide range of the commonly grown garden annuals and that one application, or at most two, made within the first week of growth were usually sufficient to affect the plant until maturity. Edgerton and Hoffman (12) working with B-Nine and other growth retardants found that the growth inhibiting effect of the retardants was enhanced with the addition of a suitable surfactant.

Timing of Application

Sachs and Hackett (39) reported that timing the application of chemicals to inhibit stem elongation depends in part on the compound selected, the immediate morphological effects on the plant, and protracted action of the compound in the plant. Timing should also refer to species and stage of shoot development rather than calendar. Chlormequat and SADH must be applied at the beginning of short day flower induction in chrysanthemum and up to 3 months before marketing in poinsettia to obtain maximum inhibition of stem elongation and minimum effects on reproductive structure.

Sachs and Hackett (39) suggested that there are reasons for the increased response to early applications of retardants: 1) the chemicals are present from the beginning of shoot elongation and, 2) for foliar applied material absorption through the young leaves is considerably greater than through mature leaves. Sachs and Maire (38), working with Alar, reported that relative humidity is another factor to consider regarding the time of application, most likely through its effect upon penetration of the material into the leaves. Application in the spring were more effective than during the summer, as application in greenhouse more effective than those applied under field conditions.

Effects of Growth Retardants

Many researchers (1, 6, 41, 45) working with the effects of CCC and Alar on plants and found that plant height, internode length, petiole length and total weight were significantly decreased over the control plants and that the color of leaves was darker than those of untreated plants. Cathey (7), Sachs et al. (36), and Zeevaart (45) suggested that reduction in weight was primarily a result of reduction in stem length. This can be attributed to inhibition of cell division or reduced mitotic activity. The number of internodes and weight of leaves of treated plants were not affected. Growth retardants are active in subapical meristems where cell division and cell elongation occur and not in the apical meristem where the leaves and nodes are produced. Riddle et al. (35) obtained the same effect that B-Nine reduced plant height, but the rate of leaf development was not affected.

Characteristics of Growth Retardants

Dick (11) reported that more aminozide was taken up by young lateral shoots than by older foliage on the main stem. From reports (21, 22) the B-Nine molecule was quite stable and resistant to breakdown and that it required more than 3 months of breakdown to occur. B-Nine was found to move freely into all areas of the plant including passage into the soil via the roots which could account for its rapid distribution within the plant. Muller (23) found that CCC residues were less in tomato fruit from the top than from the bottom of plants, and spraying the leaves resulted in higher residues in cauliflower and tomato than from soil treatments. Larson and McIntyre (19) reported CCC applied as a soil drench seemed to be more persistent in both first and second generation of plant than when CCC was applied as foliar spray. Cathey (7) reported that the effect from one application of chlormequat and related compounds was not rapidly destroyed in the plant, and the effects were carried to each new expanding leaf.

CHAPTER III

MATERIALS AND METHODS

The object of these experiments was to obtain information on leaf formation, bolting, and yield of leaf and cos lettuce as influenced by foliar sprays of two growth retardants under the different growing seasons. Determinations were made on stem length, number of leaves, and total weight of ten plants in each treatment for trial I and five plants for trial II.

Chemicals were CCC[1] and Alar.[2] Concentrations of growth retardant used in this study were: 1) CCC at 4,000, 6,000, 8,000 and 12,000 ppm. 2) Alar at 4,000, 5,000 and 6,000 ppm. The chemicals were applied to plants of two varieties of lettuce: 1) Big green[3] (leaf lettuce) and 2) Paris Island[4] (cos lettuce).

The chemicals used for treatment were dissolved in water at their specific concentrations without the addition of a surfactant. The

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[1]CCC (Cycocel, Chlormequat, 2-chloroethyl trimethylammonium chloride). Manufactured by America Cyanamid Co., Agriculture Division, Princeton, N. J. 08540.

[2]Alar (Aminozide, B-Nine 85 WP, SADH, Succinamic acid 2, 2-dimethyl hydrozide). Manufactured by Uniroyal Chemical, Division of Uniroyal, Inc., Naugatuck, Conn. 05770.

[3]Big Green is an unofficial name of a dark green selection of U.S. #1 strain of Grand Rapids lettuce made by Bobby Burk, Department of Horticulture, Oklahoma State University.

[4]Paris Island seeds were supplied by Professor W. R. Kays, the Department of Horticulture Head, Oklahoma State University.

chemicals were applied at 9:30-11:30 a.m. for each application in all trials by means of a "Jiffy Sprayer"[5] hand sprayer. The leaves were throughly wetted.

Lettuce seeds were spot seeded in Jiffy-Pots containing a soil mixture of one part sandy soil, one part peat, and one part perlite and germinated under intermittant mist. The seedlings developed cotyledon leaves in three days and were removed from the mist area and placed in a pad-and-fan cooled greenhouse. When the seedlings were 3-4 weeks of age they were transplanted to the ground bed in the greenhouse. Foliar applications of each chemical were applied one, two, and three times. This was done following transplanting to the ground bed following two, and three weeks, respectively.

The experiments were carried out in a greenhouse where the night temperature averaged 60°F and day temperature ranged from 70° to 95°F. The plants were spaced 8" x 8". Measurements were taken from ten plants of each treatment in trial I and five plants in trial II, selected at random.

Data on stem length, number of leaves per plant and total weight of plant were collected from both trials. Statistical significance of experimental results was determined by analysis of variance.

Trial I

Seeds were sown February 25, 1974 and seedling plants set into the greenhouse beds March 21, 1974. Treatments were applied first on March 28, second on April 4, and third on April 12, 1974. The treatments

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[5]Jiffy Sprayer is distributed by Jiffy-Pot Company of America, West Chicago, Ill. 60135.

consisted of: 1) control (no chemical treatment); 2) CCC at 4,000 ppm; 3) CCC at 6,000 ppm; 4) CCC at 8,000 ppm; 5) CCC at 12,000 ppm; 6) Alar at 4,000 ppm; 7) Alar at 5,000 ppm; 8) Alar at 6,000 ppm. The leaf lettuce plants in the first application were harvested and data collected April 29, while plants in the second and third application were harvested and data collected May 6, 1974.

Trial II

Seeds for the second trial were sown May 10, 1974. Seedling plants were transplanted to the ground bed June 8, 1974. The same growth retardants and concentrations used in the first trial were applied first on June 15, second on June 22, and third on June 29, 1974. The leaf and cos lettuce plants were harvested and data collected July 13 and July 14, 1974, respectively.

CHAPTER IV

RESULTS

Plant growth and development response to various number of applications and treatments of CCC and Alar was variable. Significant differences were found between growth retardants, number of applications, and chemical concentrations regarding stem length and weight of lettuce plants in all trials. Results of this study suggest that the growth retardant treatments may have a desirable effect on lettuce plants by extending the growing season to produce continously during the summer period as shown in Figures 2 and 8.

In leaf lettuce, the stem length of plants in both the spring (Figure 1) and summer trial (Figure 2) was reduced significantly among applications and treatment rates. The stem length of treated plants in the spring trial was reduced more significantly among applications but less significantly among treatment rates within each application than in the summer test. When compared to the check plants, stem length of treated plants in the spring test was reduced more significantly than in the summer test in either the single or repeated applications. The difference in stem length of treated plants by CCC and Alar in the spring test was less than in the summer test. The results of the analysis of variance for stem length are reported in Table I and II for spring and summer tests, respectively. The effects of growth retardants on the number of leaves in the spring and summer tests are shown in

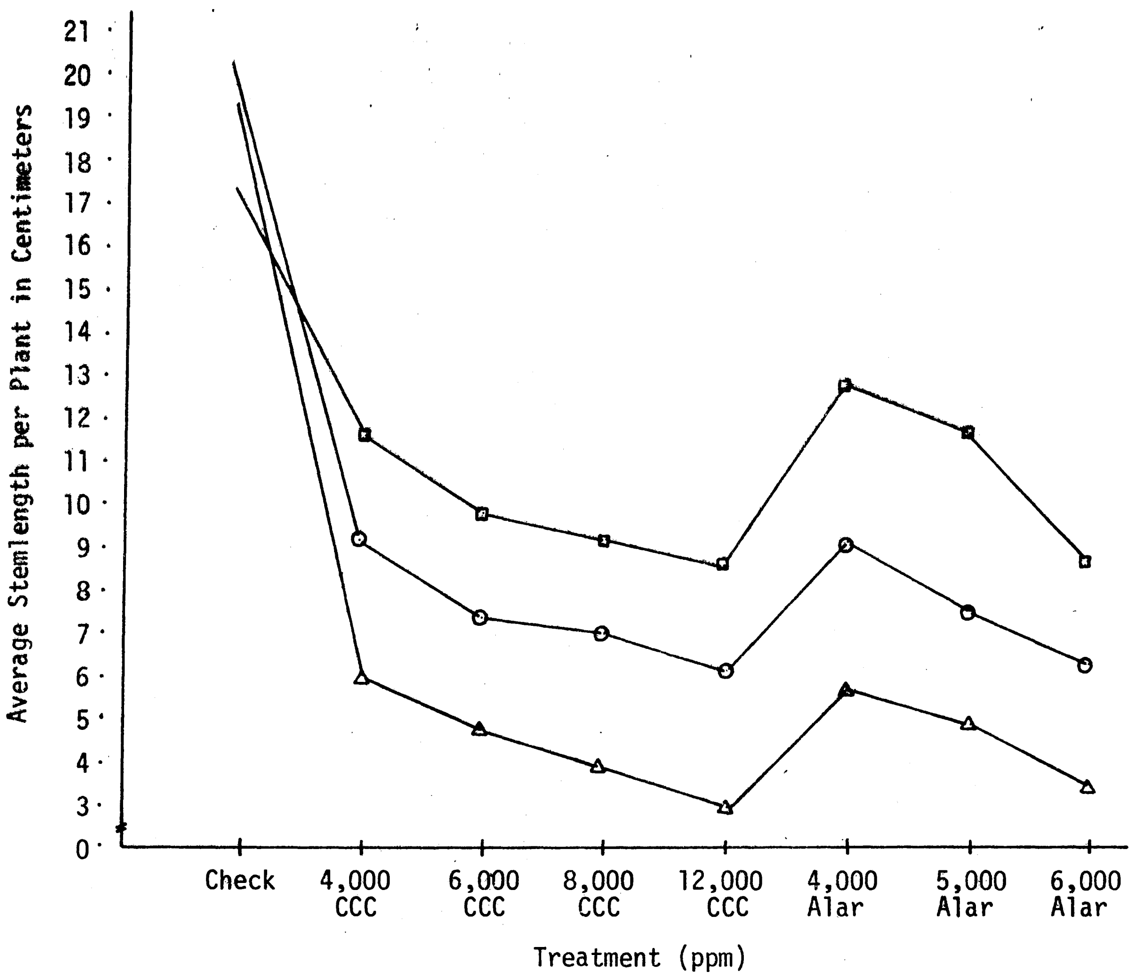

Figure 1. Effect of Spray Application of CCC and Alar on the Average Stem Length per Plant of Big Green Leaf Lettuce Trial I

□ one application, treated March 28, 1974

○ two applications, treated March 28 and April 4, 1974

△ three applications, treated March 28, April 4, and 12, 1974

(transplanted March 21, harvested for one application plants April 29, for two and three application plants May 6, 1974)

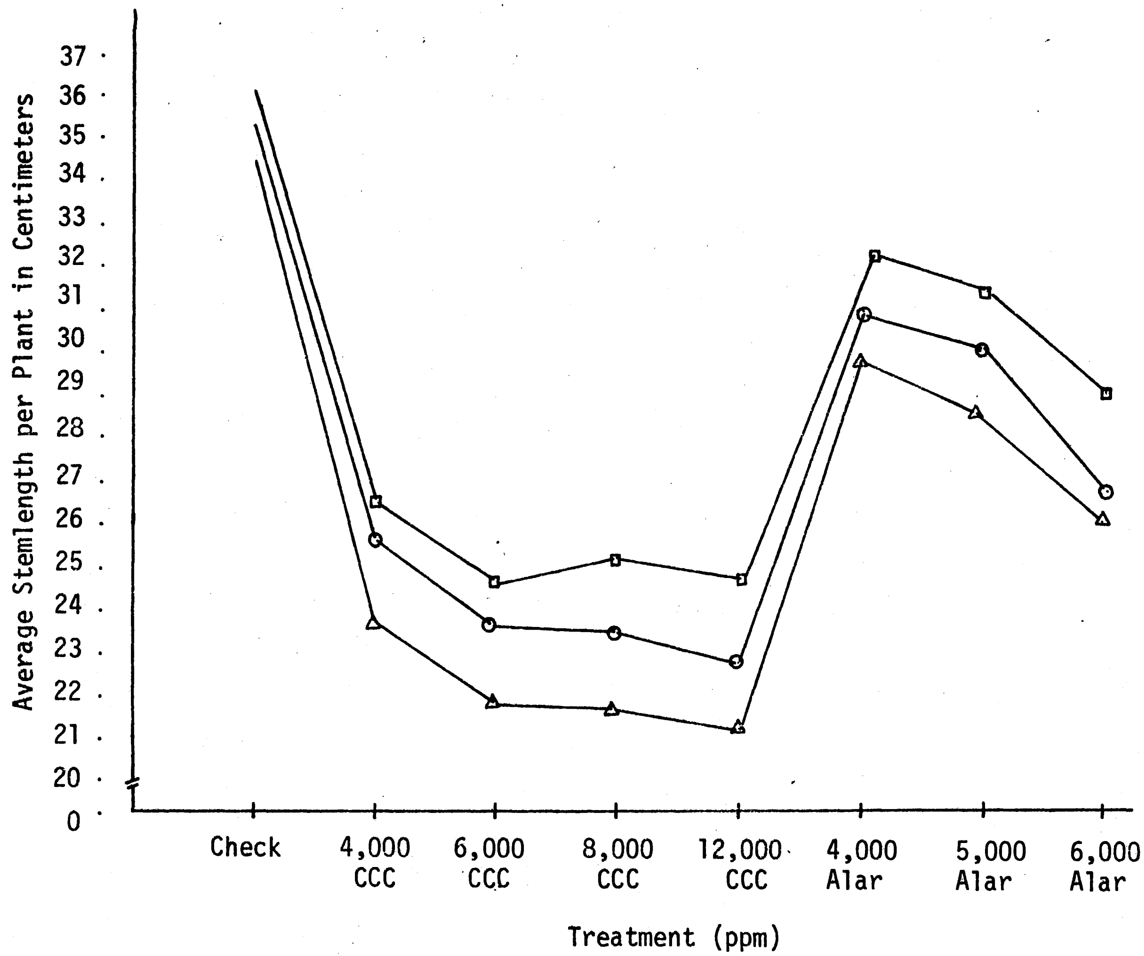

Figure 2. Effect of Spray Applications of CCC and Alar on the Average Stem Length per Plant of Big Green Leaf Lettuce Trial II

□ one application, treated June 15, 1974

○ two applications, treated June 15 and 22, 1974

△ three applications, treated June 15, 22, and 29, 1974

(transplanted June 8, harvested July 13, 1974)

TABLE I

THE EFFECT OF GROWTH RETARDANTS ON STEM LENGTH OF LEAF LETTUCE (TRIAL I)

Source	Sum of Squares	Degree of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Applications	351.8917	2	175.9470	18.2417*	3.74
Within Applications	240.3533	7	34.3361	3.5599*	2.77
Error	135.0348	14	9.6453		
Total	727.2998	23			

*Significance of 5% level. Since F .05; 2, 14 = 3.74 and F = 18.2417 > 3.74, F .05; 7, 14 = 2.77 and F = 4,6872 > 2.77.

TABLE II

THE EFFECT OF GROWTH RETARDANTS ON STEM LENGTH OF LEAF LETTUCE (TRIAL II)

Source	Sum of Squares	Degree of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Applications	398.7030	2	199.3515	7.1728*	3.74
Within Applications	911.8783	7	130.2683	4.6872*	2.77
Error	389.0970	14	27.7926		
Total	1699.6793	23			

*Significance at 5% level. Since F .05; 2, 14 = 3.74 and F = 7.1728 > 3.74, F .05; 7, 14 = 2.77 and F = 4.6872 > 2.77.

Figures 3 and 4. The number of leaves per plant was not reduced significantly among applications and treatment rates, when compared to the check plants. Table III and IV show the results of an analysis of variance for the number of leaves in both the spring and summer tests. Plant weight of the spring (Figure 5) and summer tests (Figure 6) was not reduced significantly among applications but was reduced significantly among treatment rates. When compared with the check treatment, it was found that plant weight was reduced significantly among applications and treatment rates and was reduced more significantly in spring than in summer plantings.

In cos lettuce, general effectiveness was similar but less effective than with leaf lettuce plants. The effect of growth retardants on stem length of plants in spring and summer trials are shown in Figures 7 and 8, respectively. The stem length was reduced significantly among applications and treatment rates in all trials. When compared to the check plants, stem length of treated plants in the spring trial was reduced more significantly in both applications and treatment rates than in summer trial. The effect of growth retardants on stem length are reported in Table V and VI for the spring and summer trials, respectively. The number of leaves per plant in spring (Figure 9) and summer trials (Figure 10) was not reduced significantly among applications and treatment rates when compared to the check plants. The results of the growth retardants effect on the number of leaves per plant by means of analysis of variance are reported in Table VII and VIII for spring and summer trials, respectively. The effect of growth retardants on plant weight are given in Figure 11 for spring trial and Figure 12 for summer trial. Plant weight was not reduced significantly among applications

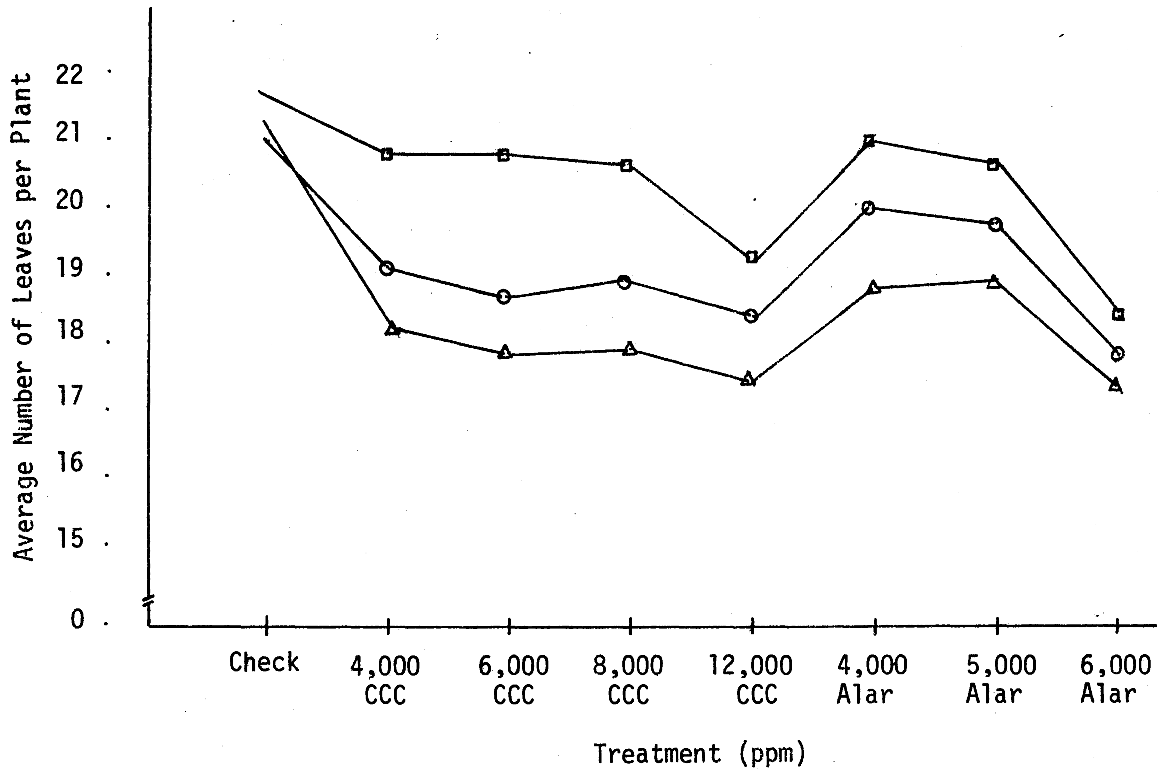

Figure 3. Effect of Spray Applications of CCC and Alar on the Average Number of Big Green Leaf Lettuce Trial I

□ one application, treated March 28, 1974

○ two applications, treated March 28 and April 4, 1974

△ three applications, treated March 28, April 4, and 12, 1974

(transplanted March 21, harvested for one application plants April 29, for two and three application plants May 6, 1974)

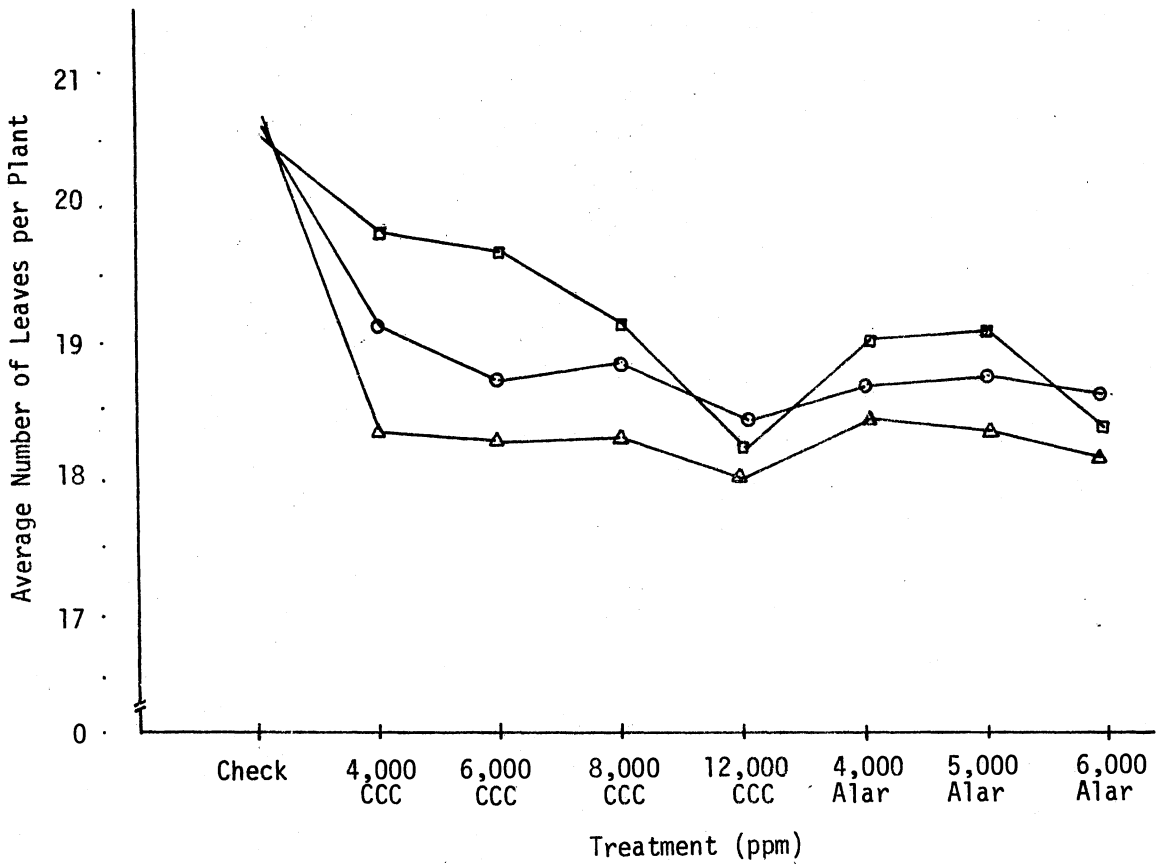

Figure 4. Effect of Spray Applications of CCC and Alar on the Average Number of Leaves of Big Green Leaf Lettuce Trial II

□ one application, treated June 15, 1974

○ two applications, treated June 15 and 22, 1974

△ three applications, treated June 15, 22, and 29, 1974

(transplanted June 8, harvested July 13, 1974)

TABLE III

THE EFFECT OF GROWTH RETARDANTS ON NUMBER OF LEAVES OF LEAF LETTUCE (TRIAL I)

Source	Sum of Squares	Degree of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Applications	40.6933	2	10.3467	2.5673	3.74
Within Applications	130.2096	7	18.6013	2.3470	2.77
Error	110.3967	14	7.9255		
Total	281.2996	23			

TABLE IV

THE EFFECT OF GROWTH RETARDANTS ON NUMBER OF LEAVES OF LEAF LETTUCE (TRIAL II)

Source	Sum of Squares	Degree of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Applications	8.4900	2	4.2450	1.6980	3.74
Within Applications	30.3870	7	4.3410	1.7370	2.77
Error	34.9830	14	2.4987		
Total	73.8600	23			

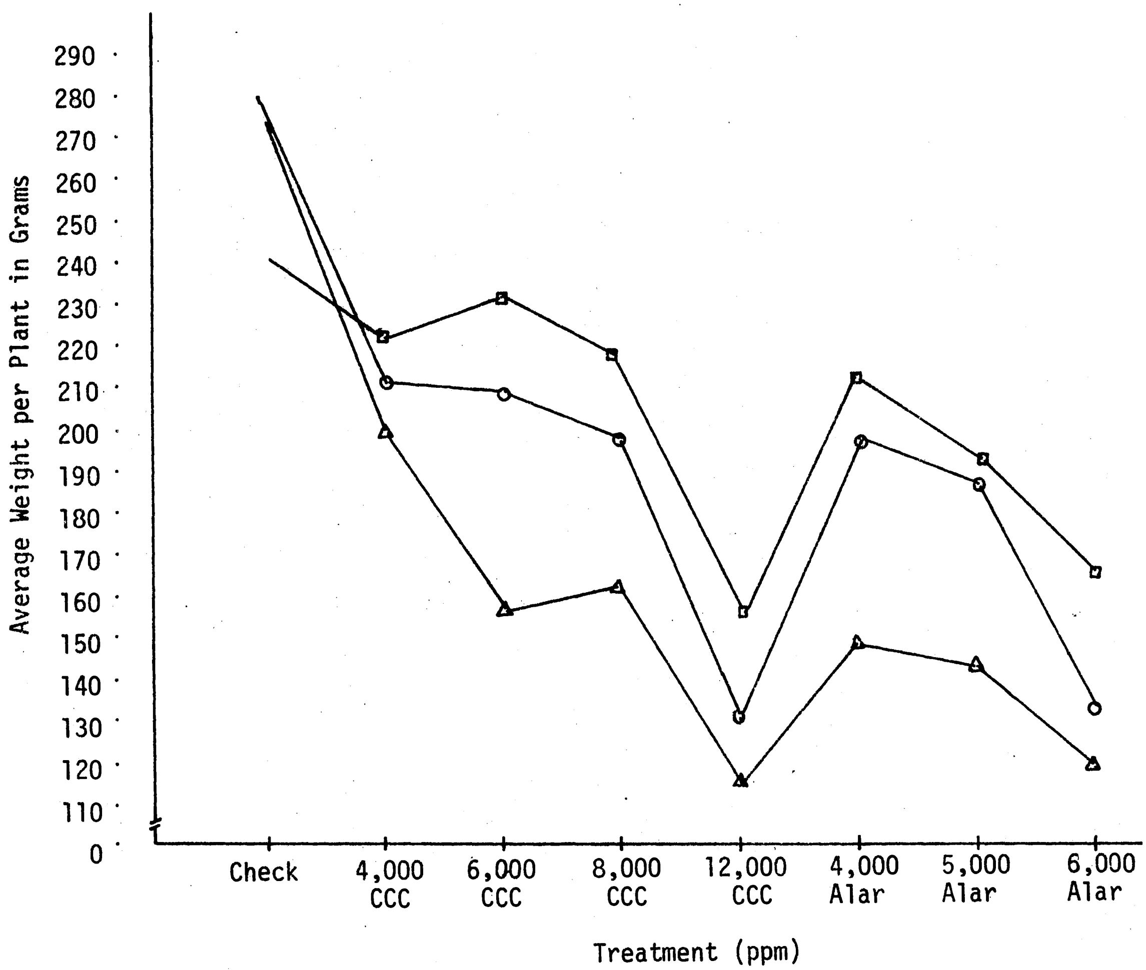

Figure 5. Effect of Spray Applications of CCC and Alar on the Average Weight per Plant of Big Green Leaf Lettuce Trial II

□ one application, treated March 28, 1974

○ two applications, treated March 28 and April 4, 1974

△ three applications, treated March 28, April 4 and 12, 1974

(transplanted March 21, harvested for one application plants April 28, for two and three application plants May 6, 1974)

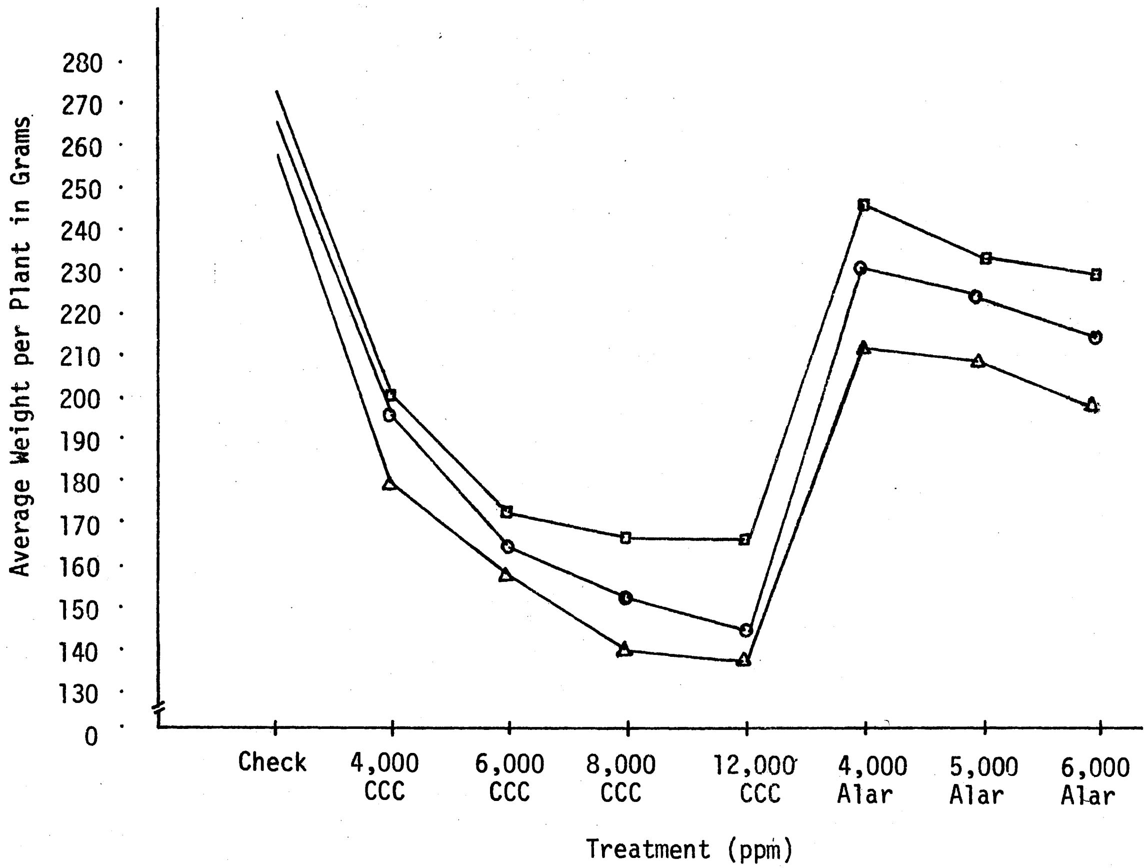

Figure 6. Effect of Spray Applications of CCC and Alar on the Average Weight per Plant of Big Green Leaf Lettuce Trial II

□ one application, treated June 15, 1974

○ two applications, treated June 15 and 22, 1974

△ three applications, treated June 15, 22, and 29, 1974

(transplanted June 8, harvested July 13, 1974)

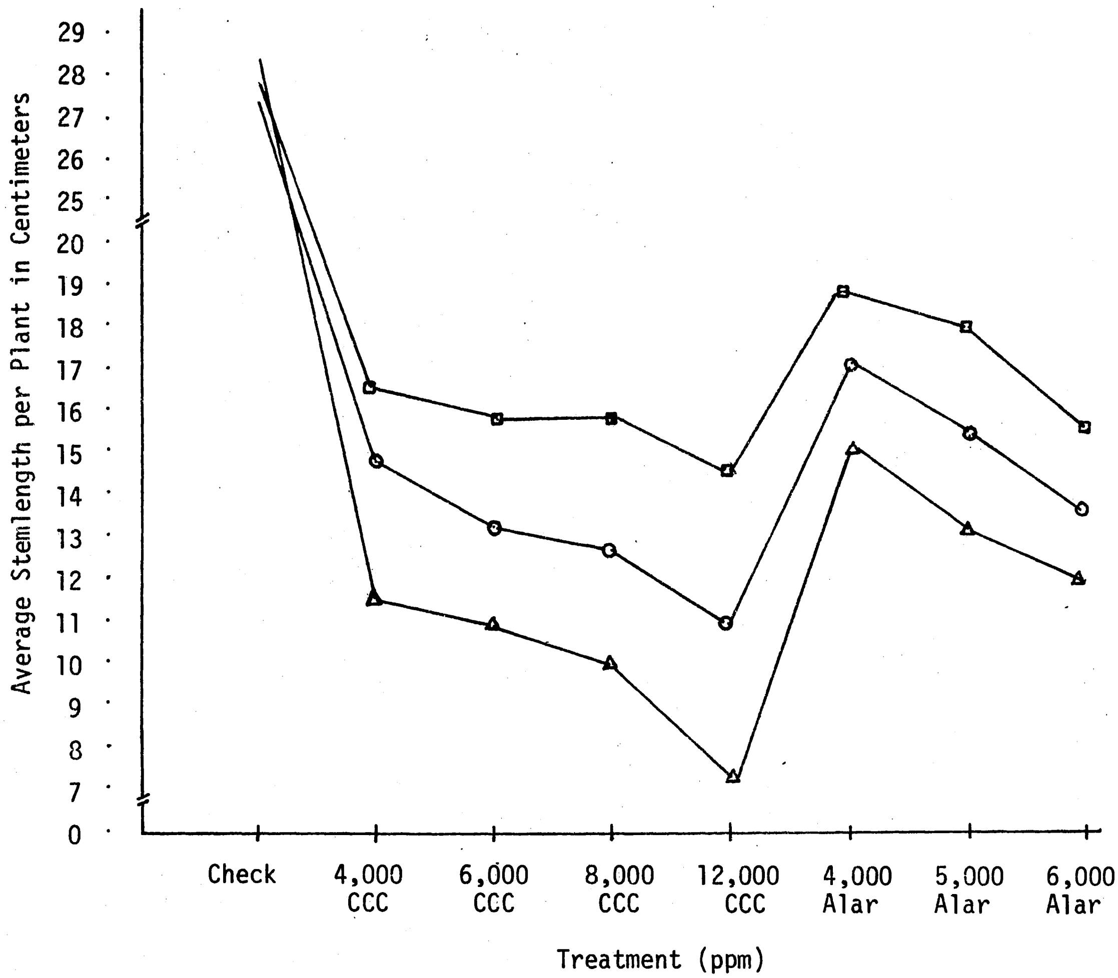

Figure 7. Effect of Spray Applications of CCC and Alar on the Average Stem Length per Plant of Paris Island Cos Lettuce Trial I

□ one application, treated March 28, 1974

○ two applications, treated March 28 and April 4, 1974

△ three applications, treated March 28, April 4, and 12, 1974

(transplanted March 21, harvested May 6, 1974)

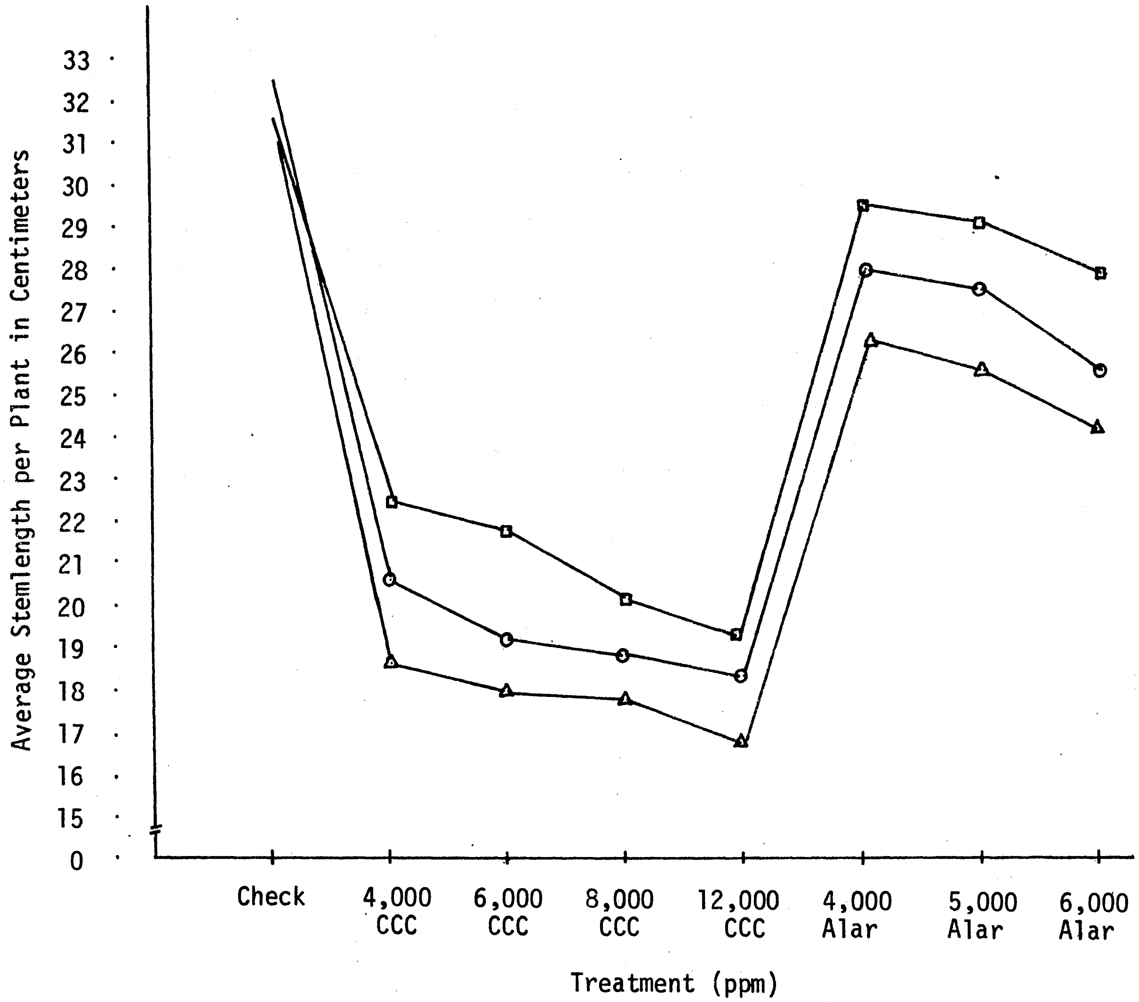

Figure 8. Effect of Spray Applications of CCC and Alar on the Average Stem Length per Plant of Paris Island Cos Lettuce Trial II

□ one application, treated June 15, 1974

○ two applications, treated June 15 and 22, 1974

△ three applications, treated June 15, 22 and 29, 1974

(transplanted June 8, harvested July 14, 1974)

TABLE V

THE EFFECT OF GROWTH RETARDANTS ON STEM LENGTH
OF COS LETTUCE (TRIAL I)

Source	Sum of Squares	Degree of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Applications	87.9597	2	43.9798	8.1881*	3.74
Within Application	425.3078	7	60.7582	11.3119*	2.77
Error	75.1965	14	5.3712		
Total	588.4640	23			

*Significance at 5% level. Since F .05; 2, 14 = 3.74 and F = 8.1881 >3.74, f .05; 7, 14 = 12.779 and F = 11.3119 > 2.77

TABLE VI

THE EFFECT OF GROWTH RETARDANTS ON STEM LENGTH
OF COS LETTUCE (TRIAL II)

Source	Sum of Squares	Degree of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Applications	55.5410	2	27.7705	4.2678*	3.74
Within Applications	1106.6620	7	158.0946	24.2961*	2.77
Error	91.1163	14	6.5070		
Total	1253.3193	23			

*Significance at 5% level. Since F .05; 2, 14 = 3.74 and F = 4.2678 > 3.74, F .05; 7, 14 = 2.77 and F = 24.2961 > 2.77

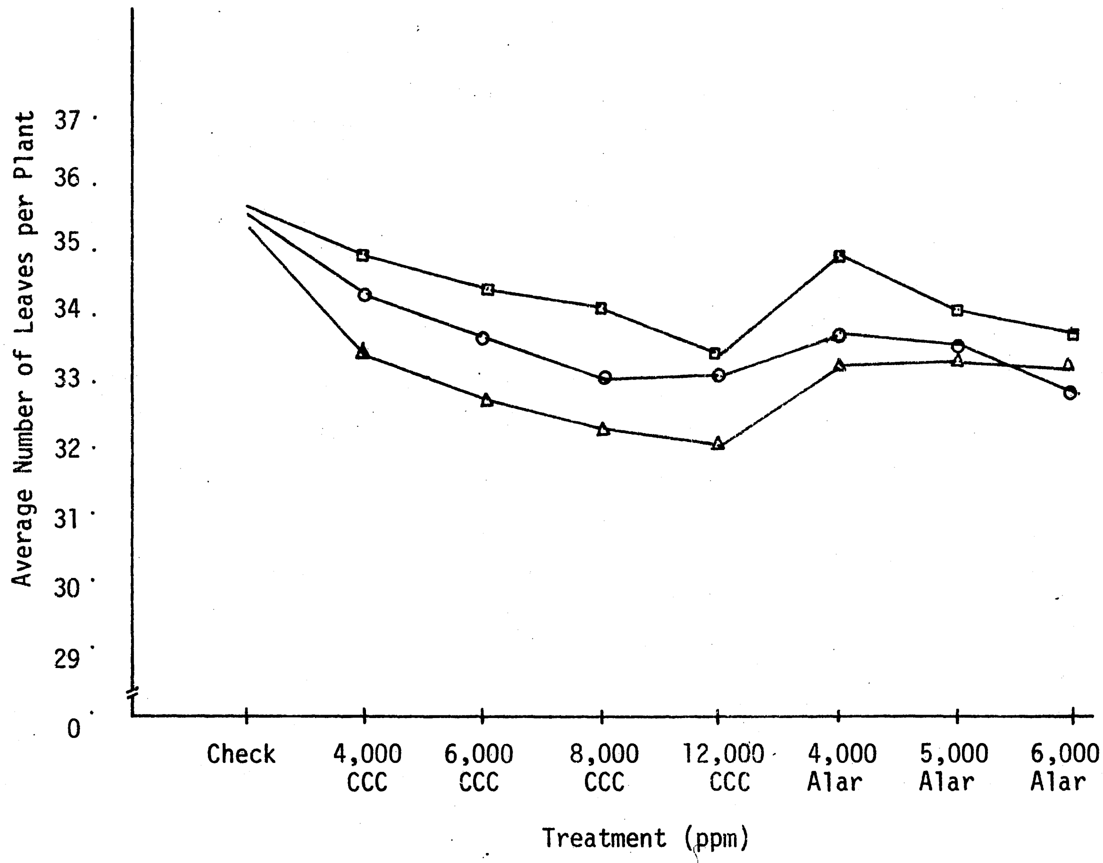

Figure 9. Effect of Applications of CCC and Alar on the Average Number of Leaves per Plant of Paris Island Cos Lettuce Trial I

- □ one application, treated March 28, 1976
- ○ two applications, treated March 28 and April 4, 1974
- △ three applications, treated March 28, April 4, and 12, 1974

(transplanted March 21, harvested May 6, 1974)

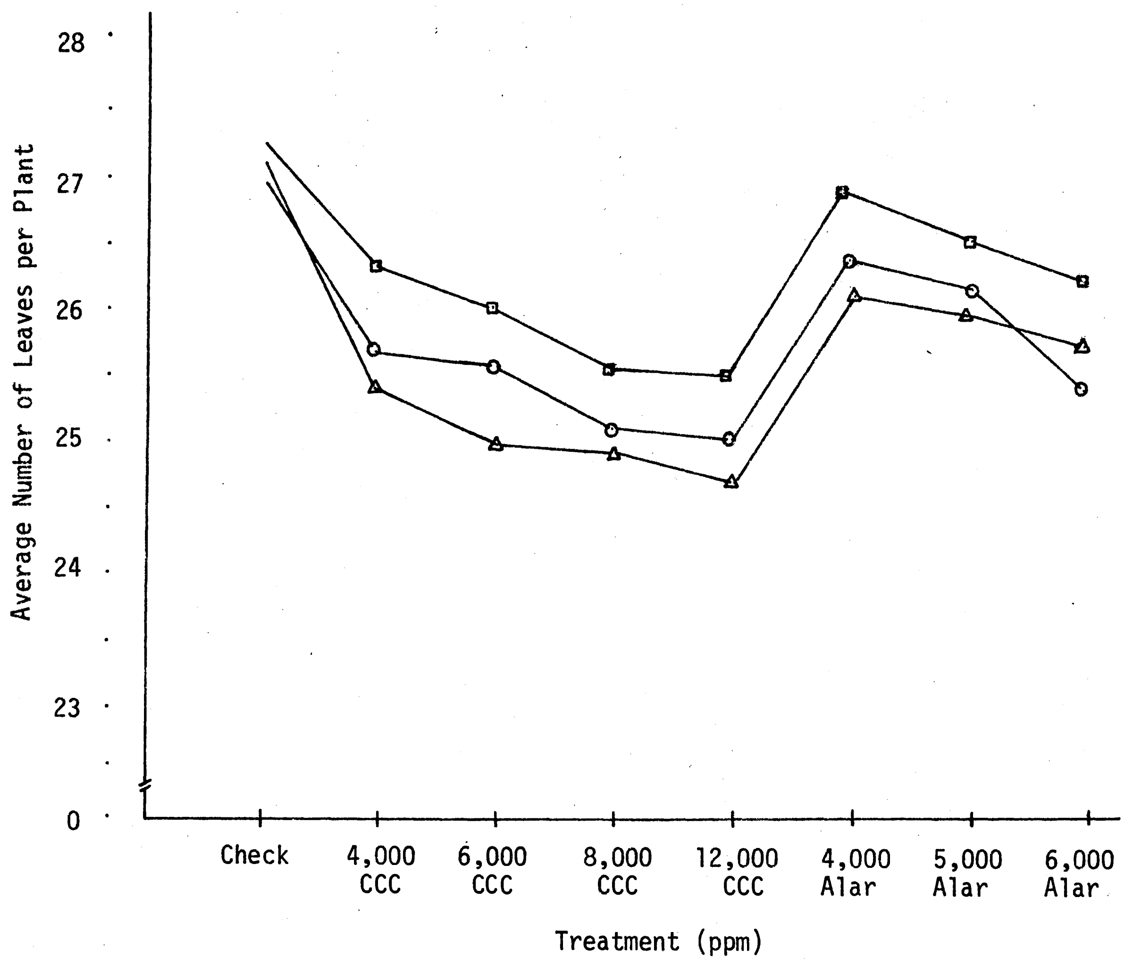

Figure 10. Effect of Spray Applications of CCC and Alar on the Average Number of Leaves of Paris Island Cos Lettuce Trial II

□ one application, treated June 15, 1974

○ two applications, treated June 15 and 22, 1974

△ three applications, treated June 15, 22, and 29, 1974

(transplanted June 8, harvested July 14, 1974)

TABLE VII

THE EFFECT OF GROWTH RETARDANTS ON NUMBER OF LEAVES OF COS LETTUCE (TRIAL I)

Source	Sum of Squares	Degree of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Applications	18.0015	2	9.0080	0.8126	3.74
Within Applications	80.1670	7	11.4524	1.0349	2.77
Error	155.0655	14	11.0761		
Total	243.2340	23			

TABLE VIII

THE EFFECT OF GROWTH RETARDANTS ON NUMBER OF LEAVES OF COS LETTUCE (TRIAL II)

Source	Sum of Squares	Degree of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Applications	5.0840	2	2.5420	0.6793	3.74
Within Applications	27.7170	7	3.9596	1.0581	2.77
Error	52.3890	14	3.7421		
Total	85.1900	23			

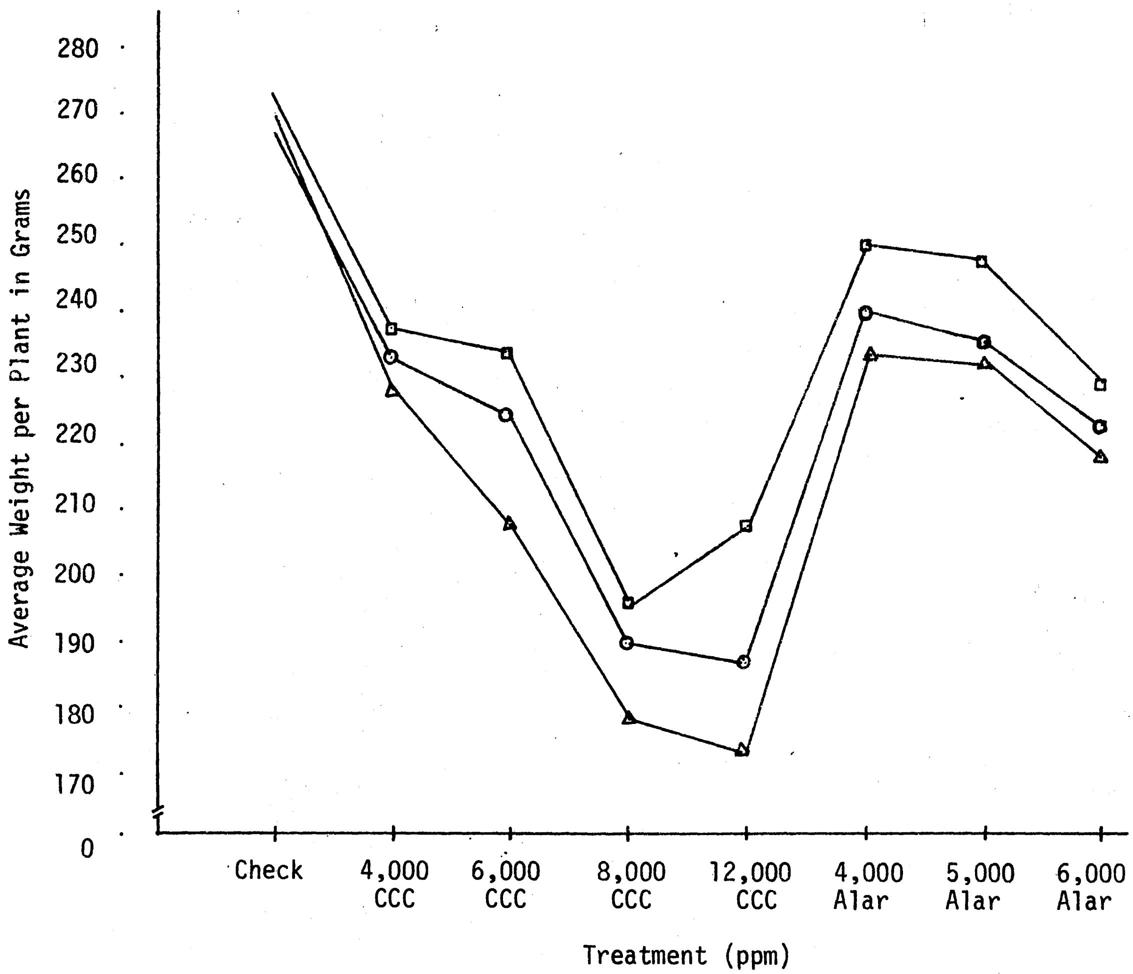

Figure 11. Effect of Spray Applications of CCC and Alar on the Average Weight per Plant of Paris Island Cos Lettuce Trial I

□ one application, treated March 28, 1974

○ two applications, treated March 28, and April 4, 1974

△ three applications, treated March 28, April 4, and 12, 1974

(transplanted March 21, harvested May 6, 1974)

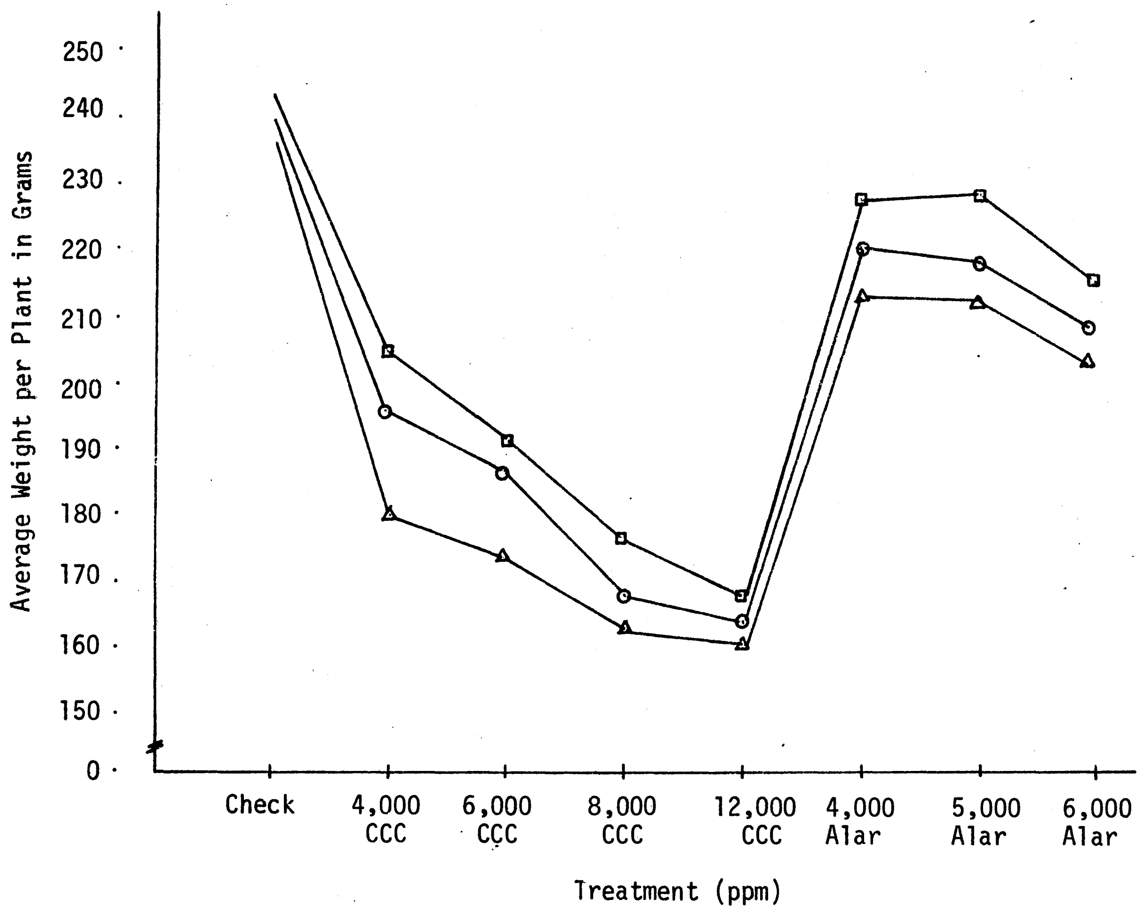

Figure 12. Effect of Spray Applications of CCC and Alar on the Average Weight per Plant of Paris Island Cos Lettuce Trial II

□ one application, treated June 15, 1974

○ two applications, treated June 15 and 22, 1974

△ three applications, treated June 15, 22, and 29, 1974

(transplanted June 8, harvested July 14, 1974)

whereas it was reduced significantly among treatment rates within each application. When compared to the check plants, plant weight was reduced significantly among applications and treatment rates in both trials.

When the check and treated plants between spring and summer trials were compared, it was observed that the leaves were wider with shorter petioles and darker green leaves as well as having shorter and thicker stems in the spring than in the summer trial. All concentrations caused the leaves of both lettuce varieties to develop transitory chlorosis, especially the margin of leaves. The leaves of leaf lettuce plants showed more serious marginal burn and longer-lasting chlorotic spot than did the leaves of the cos lettuce plants. The most affected resulted from spraying with higher concentration of CCC. This undesirable side-effect dissappeared gradually when the plants were mature. The growth retardant chemicals enhanced darker green leaves than the check plants but CCC showed a greater effect than did Alar.

Heading of cos lettuce plants was delayed more by CCC than by Alar. Formation of spiralled leaves was also prevented by the growth retardants. Bolting of plants of both lettuce varieties was significantly delayed by both growth retardants (Table I, II, V and VI).

CHAPTER V

DISCUSSION AND CONCLUSION

The production of leaf and cos lettuce in Oklahoma can be successful during the cool months of the year. Production during the summer is generally unsuccessful due to the initiation and rapid elongation of seed stalks during that period. The treatment of both types of lettuce cultivars with spray applications of various number of applications and treatments of CCC and Alar apparently activated chemical change or changes within the plants which delayed the initiation or caused suppression of stem elongation of seed stalks even when temperatures were high (70° to 95°F).

From the study reported herein, the effect of growth retardants in the spring trial was more pronounced than in the summer trial and CCC showed more typical retarding than Alar. The whole development of plant was delayed. The different effect between CCC and Alar was more evident during the summer period, particularly in stem length retardation. Trial II was carried out during the summer period and ended July 14, 1974 at which time the daily temperature rose to 95°F and the relative humidity was very low. When one compares the difference between the spring and summer planting, the stem length of both lettuce cultivars elongated more rapidly during the summer period than during the spring period. Apparently when the temperature becomes high and the humidity is low the growth retardants are not as effective in inhibiting bolting.

This might be due to either the fact that high temperature stimulated the metabolic process within the plants to produce more gibberellic acid which initiated bolting or that the combination of high temperature and low humidity affected the penetration and absorption of growth retardant chemicals into the leaves. Similar results were reported by Pall (28). The growth retardants showed more effect on stem length reduction in both trials rather than a decrease in the number of leaves, even though the leaf lettuce plants in trial I were not harvested at the same time. The number of applications had no significant effect on reduction of plant weight but was a significant reduction in weight with all treatment rates when compared with the check plants. Based on the statistical analysis of both Big Green and Paris Island varieties during the spring and summer periods, it was considered that the main effect of growth retardants was on the stem meristem (subapical meristem) rather than on the leaf meristem (apical meristem). This supports work by Sachs et al. (36), Cathey (7), and Zeevaart (45) in their reports.

When repeated applications of chemicals were made, the effects were greater than from single application. Neither growth retardant significantly reduced plant weight between applications within each treatment. The repeated applications and higher concentration of both growth retardants satisfactorily delayed bolting and spiralled leaf formation but the plant size with repeated applications and higher concentration of both growth retardants was reduced much more than from single application when compared to the check plants. The plants were smaller than desired for commercial production. It may be necessary to choose between single application of high concentration applied to plants the first week after the seedlings are transplanted to affect the plant until maturity or use repeated applications of lower concentration which would also produce commercially acceptable material. This is supported by Cathey (7), Sachs and Hackett (39), and was a general observation in this test.

The treated plants were darker in color than the check plants. This might be due to the growth retardants preventing chlorophyll destruction from gibberellic acid. Gibberellic acid affects chlorophyll anabolism by: 1) reducing the synthesis of pigment complement and 2) changing the ratio of pigment present (9). Another possibility is that they had the same effect as benzyladenine by increased chlorophyll synthesis as mediated by inducing the production of proteins (13).

The treated plants were judged by qualified horticulturists at Oklahoma State University to be of higher quality than the check plants. This consideration was based on size, shape, and color of the leaves. The leaves were more uniform in size, none were extremely large or small. The shape of the plant was more compact due to the reduction in petiole and stem length. This would reduce waste when the lettuce was used and would extend the growing season due to delayed bolting. The green color of leaves of treated plants was more intense than were those of the check plants. Growth retardants in these tests produce plants that were of more salable quality than those not treated.

CHAPTER VI

SUMMARY

The study reported herein relates to the effect of spray applications of various number of applications and concentration of CCC and Alar on growth and development of leaf and cos lettuce.

Two experiments utilizing greenhouse grown plants of leaf and cos lettuce were sprayed either one, two, or three times with growth retardants. This was done following transplanting to the ground bed in the greenhouse for one, two, and three weeks, respectively. The height and total weight of both lettuce varieties Big Green and Paris Island were reduced much more in spring than summer, and CCC showed more effect than did Alar. Neither growth retardant reduced significantly the number of leaves per plant among applications and treatment rates as compared to the check plants, but plant weight was reduced significantly among treatment rates within each application as compared to the check plants. Bolting, and especially in the spiralled leaves of cos lettuce, was reduced by both growth retardants. The greater the number of applications, or the higher the concentration of growth retardants, the more the plants growth and development was retarded. Thus, lettuce plants should be sprayed repeatedly by the low concentration of growth retardants to achieve control of bolting and have the least effect on plant yield.

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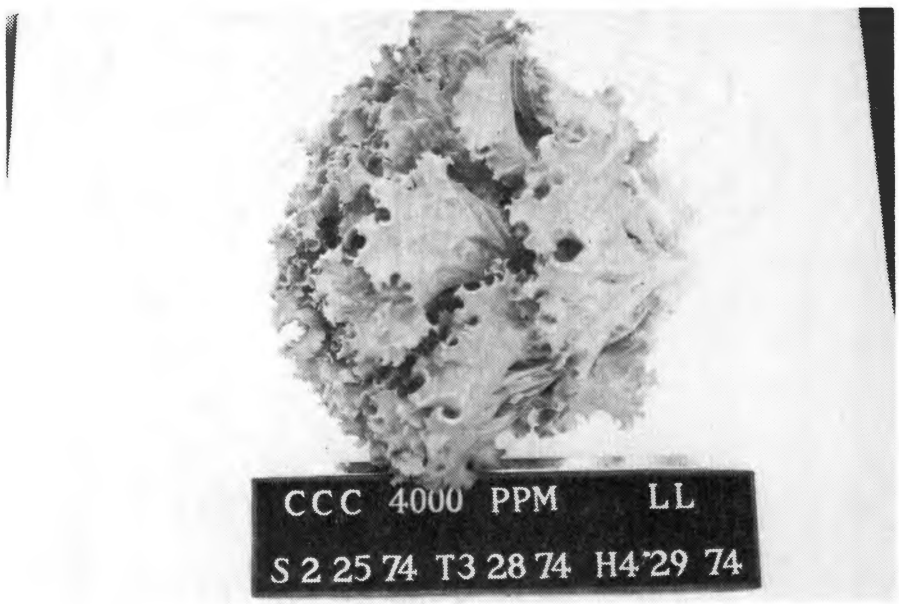
APPENDIXES

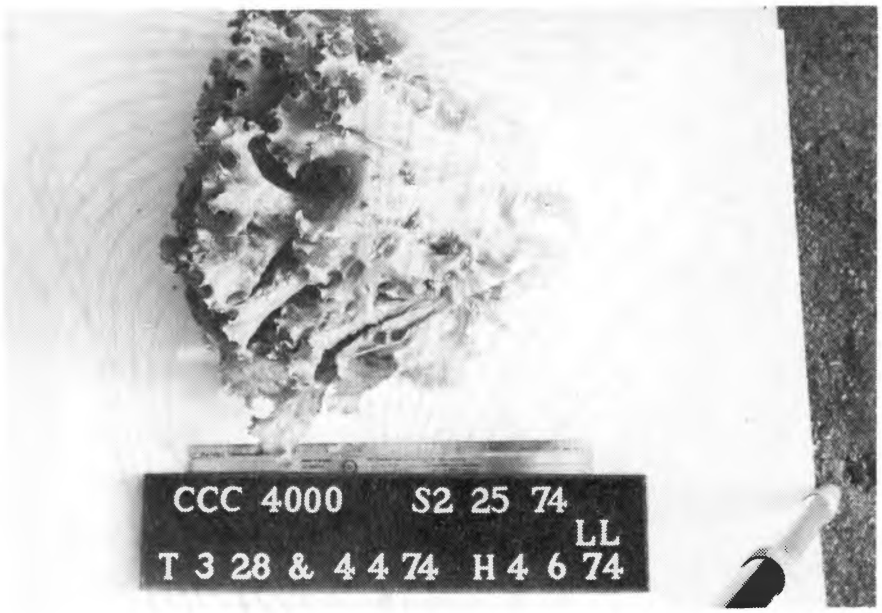
The Check Plant of Big Green Leaf Lettuce
(No chemical treatment)

APPENDIX B



The Effect of One Application of CCC at 4,000 ppm on the Plant Height Big Green Leaf Lettuce

APPENDIX C

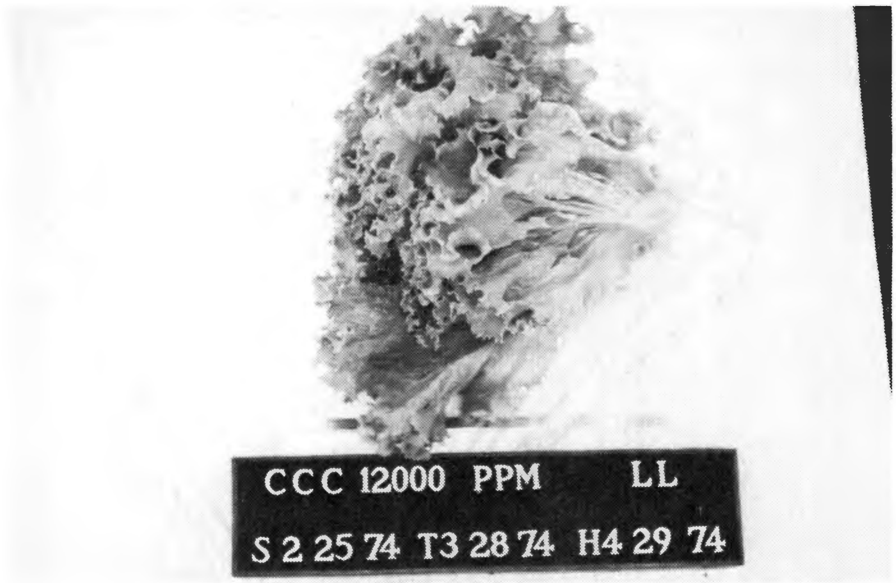


The Effect of Two Applications of CCC at 4,000 ppm on Plant Height of Big Green Leaf Lettuce

APPENDIX D

The Effect of Three Applications of CCC at 4,000 ppm
on Plant Height of Big Green Leaf Lettuce

APPENDIX E



The Effect of One Application of CCC at 12,000 ppm
on Plant Height of Big Green Leaf Lettuce

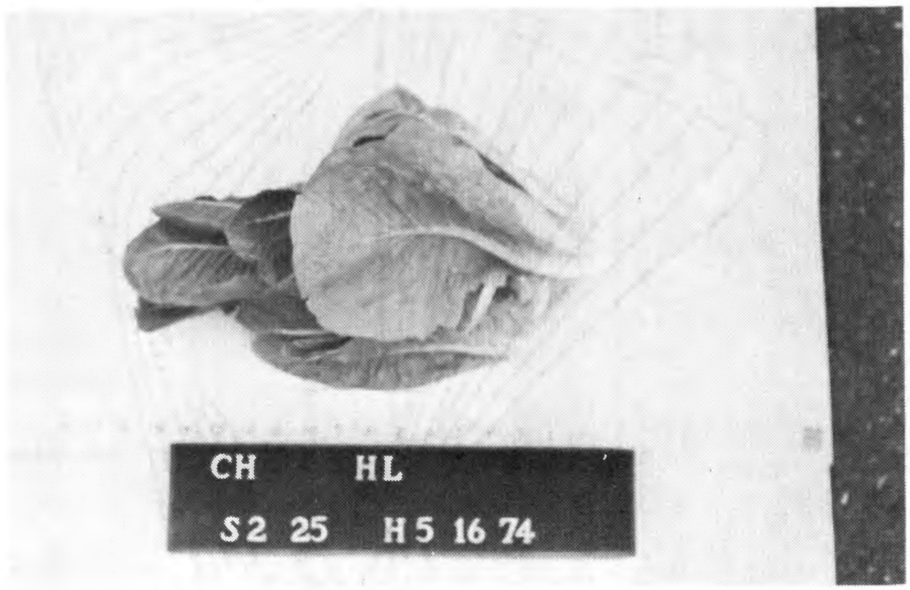
APPENDIX F

The Effect of Two Applications of CCC at 12,000 ppm on Plant Height of Big Green Leaf Lettuce

APPENDIX G

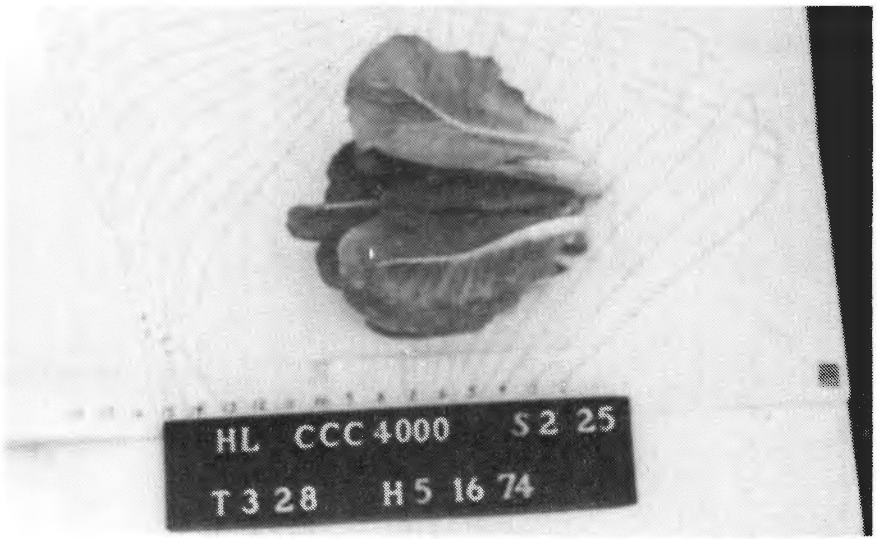
The Effect of the Three Applications of CCC at 12,000 ppm on Plant Height of Big Green Leaf Lettuce

APPENDIX H



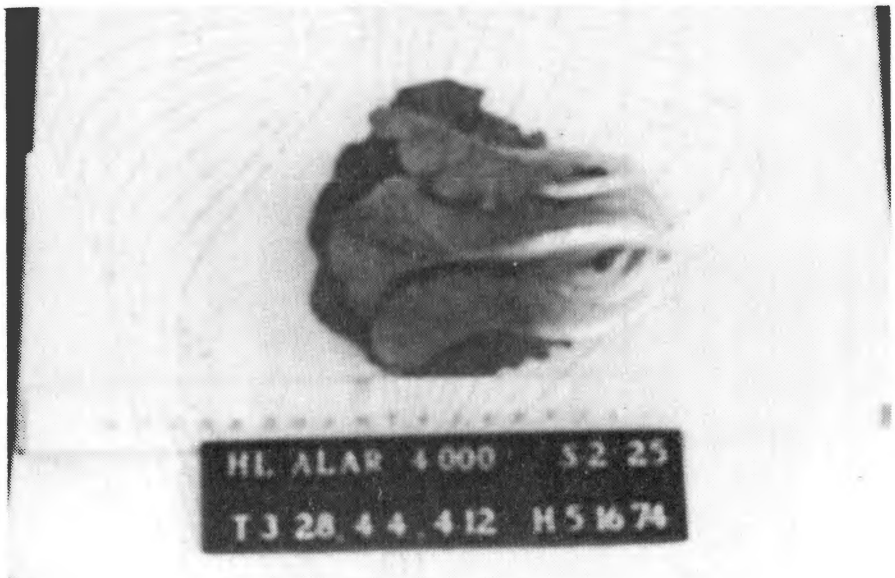
The Check Plant of Paris Island Cos Lettuce
Showing Spiralled Leaves and Bolting

APPENDIX I



The Effect of One Application of CCC 4,000 ppm on Plant Height of Green Island Cos Lettuce

APPENDIX J



The Effect of Two Applications of Alar at 4,000 ppm on Plant Height of Paris Island Cos Lettuce γ

VITA

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Master of Science

Thesis: THE EFFECTS OF VARIOUS NUMBER OF APPLICATIONS AND TREATMENTS OF GROWTH RETARDANTS ON LEAF FORMATION, BOLTING, AND YIELD OF LEAF AND COS LETTUCE (LACTUCA SATIVA L.)

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