THE EFFECT OF CERTAIN GROWTH RETARDANTS ON PLANT GROWTH AND SEED STALK RETARDATION ON LEAF LETTUCE

By

WILLIS OTIS JOHNSON

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1967

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1969

THE EFFECT OF CERTAIN GROWTH RETARDANTS ON PLANT GROWTH AND SEED STALK RETARDATION OF LEAF LETTUCE

Thesis Approved:

F. A. Ramshe
Thesis Adviser
W. R. Kays
R. Mac Irving
Robert M. Ahring
D. D. Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

During the course of this study the author has had much help and advice from several members of the Oklahoma State University Department of Horticulture. Sincere thanks is due Professor F. A. Romshe, my major professor, whose initial guidance and continued cooperation made possible the completion of this thesis. Grateful appreciation is also due Dr. R. Mac Irving for his patient assistance and suggestions, which with his encouragement and boundless enthusiasm, helped me over one rough spot after another. Indebtedness is also due to Professor W. R. Kays, the department head, for his initial guidance and cooperation.

Acknowledgement is made to Mr. Bobby Burk for his donating some of the lettuce plants used and technical assistance provided.

Further acknowledgement is made to the faculty members of the Horticulture Department for their help and friendship during my studies at this university.

Finally, thanks is due to the Uniroyal Chemical Division of UNIROYAL, Inc. who donated the Alar used in these studies.

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CHAPTER I

INTRODUCTION

The persistence of seed stalk development during the summer has long been a major problem of year-round leaf lettuce production. Maximum production of high quality leaf lettuce cannot be achieved when the terperatures are high (70° to 80°F) and the day lengths are long (10 to 16 hours) (2, 13, 14, 20). Since these conditions are prevalent from May to September in Oklahoma, the production of quality leaf lettuce is almost precluded during this period.

The objective of this study was to determine if seed stalk initiation can be inhibited by nullifying plant responses to the environmental conditions with selected growth retardants.

CHAPTER II

LITERATURE REVIEW

At the time this research problem was planned there was no published literature available regarding the effect of growth retardants on the inhibition of seed stalk initiation in leaf lettuce, although they have been reported effective in retarding plant growth in a wide range of genera and species.

Gibberelin Like Responses

The generally known and usually described plant symptoms of bolting in leaf lettuce are characterized by elongated internodes and leaves, although they are normal in shape, are slightly larger in size and paler green in color. These symptoms are similar to those found by Marth et al. (10) and Bukovac and Wittwer (1) when plants of various genera and species were treated with gibberellic acid.

Bukovac and Wittwer (2) compared the reproductive responses of Great Lakes cultivar head lettuce plants which had been vernalized, to lettuce plants which had been treated with gibberellic acid. They found that internodal elongation, leaf size and color of the vernalized plants were quite similar to the gibberellin treated plants. Harrington (7) found that spraying a solution containing 3 to 10 ppm of gibberellic acid during the 4 to 8 leaf stages caused lettuce to bolt and produce a seed crop two weeks earlier than nontreated plants. These investigators

suggest that the natural occurring process of bolting in leaf lettuce is similar to the bolting induced by treating lettuce plants with gibberelic 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.

The Causes of Bolting

Several investigators have studied the environmental conditions most conducive to seed stalk development in lettuce. Thompson and Knott (20) found that temperature was the most important single factor influencing the bolting of lettuce. While long days did cause seed stalks to elongate more rapidly, daylength did not hasten initiation. Rappaport and Wittwer (14) found that non-vernalized lettuce plants flowered only when night temperatures were high (above 65°F), independent of daylength. Rappaport and Wittwer (15) also observed that the number of days preceding the appearance of flower parts in the cultivar Grand Rapids varied only slightly with the length of day, but showed a marked response to night temperatures above 65°F. Raleigh (13) suggested that day temperature could be in the higher ranges (70° to 80°F) without undue seed stalk development if the night temperature was cool (50°F).

Growth Retardants

Since high temperatures and long days prevail during the summers in Oklahoma, the production of quality leaf lettuce during this period is all but precluded. Some means of controlling bolting therefore, would be a great aid. A possible method is thought to be the use of growth

retardants.

There is general concensus among investigators that growth retardants actually cause a reduction of internodal length by inhibiting cell division and cell elongation in the sub-apical meristem (3). Thus, growth retardants may be used to inhibit cell division and cell elongation that cause the development of seed stalks in leaf lettuce. However, the manner in which internodes are shortened by growth retardants is a matter of controversy. There have been at least four possible modes of action proposed.

One theory is that growth retardants may cause inhibitions which are not directly related to either gibberellin or auxin metabolism. There is considerable evidence to support this particular position. Kuraishi and Muir (9) found that the effect of CCC on the growth of Raphanus leaf discs was not reversed, either by gibberellic acid or auxin. Added support was given by Cleland (4) in his work with the oat plant. He found that growth retardants appeared to act by interfering with auxin metabolism of the tissue and by exerting an inhibiting effect on growth of a non-hormonal aspect. In addition, he found that auxins would not completely reverse the dwarfing effect of growth retardants. Just what the non-hormonal action is, remains unknown. Reed et al. (16) working with B-9 (Alar) found that it caused inhibition of shoot elongation by inhibiting tryptamine through diamine oxidase. This could not be reversed by adding either auxins or gibberellin. Cathey (3) also suggested that growth retardants caused an inhibition that could not be reversed by gibberellin or auxin when he found that growth retardants were not analogs of any known growth substances.

A second possibility is that growth retardant substances block the

synthesis of gibberellic acid. Kende et al. (8) found that CCC and AMO-1618 prevented the synthesis of gibberellic acid in Fusarium moniliforme. The results of such a mode of action would be that the growth retardants become competitive inhibitors of endogenous growth, but would be reversable if more gibberellic acid was added. Experiments by Sachs et al. (18) and Tolbert (21) also suggest that such an inhibition of gibberellin synthesis may occur.

A third possibility is that the growth retardants affect auxin metabolism in plant tissue. Halevy (6) suggested that gibberellic acid inhibited and growth retardants (Alar, CCC and AMO-1618 in this instance) stimulated the activity of peroxidase and indoleacetic acid oxidase in cucumber seedlings. Kuraishi and Muir (9) found that the inhibitory effect of CCC on coleoptile growth was overcome by high concentrations of IAA-oxidase and other auxin metabolism, thereby lowering the auxin level within the plant.

The fourth theory is that growth retardants may compete with gibberellin at the site of gibberellic acid action. This was the prevalent theory in early reports, but at the present time there is little evidence of support. Cleland (4) observed that although AMO-1618 possessed the ability to strongly inhibit gibberellin-induced elongation, it did not act at the site of gibberellin action. Thus, according to Cleland, AMO-1618 is not an anti-gibberellin. Kuraishi and Muir (9) found that inhibitory effect of CCC could not be reversed by applications of gibberellic acid and concluded that CCC was not an anti-gibberellin. Cathey (3) concluded that growth retardants were not anti-gibberellins when he found that they were not analogs of any known growth promoting substances.

Review of Methods of Application

Cathey (3) reported that spary applications of growth retardants were sufficiently active to serve as a method of treating most plants. It was reported that growth retardants applied as foliar sprays, controlled internode elongation in varied daylength treatments. Some of the plants tested were azalea, poinsettia, petunia and zinnia. It was found that one application (or at most two) made within the first weeks of growth was usually sufficient to supress stem elongation.

Martin and Williams (12) working with radioactive B-9 on apple seedlings, used various methods of applications. Results were obtained after various time periods using autoradiographs and showed that B-9 was quite mobile and comparable to many inorganic ions in speed of movement. Edgerton and Hoffman (5) working with B-9 and other growth retardants, found that the growth inhibiting effect of the retardants was enhanced with the addition of a suitable surfactant. It was also noted that growth retardants should not be applied with other chemicals (fertilizers or pesticides) because the interaction of the chemicals could possibly damage the plants. They should be sprayed on the foliage to the point of runoff.

Wirwille and Mitchell (22) reported that the concentration of growth retardants should be carefully regulated and uniformly applied. They found that if the concentration of AMO-1618 was too high that it would injure plants by checking expansion of the primary leaves and cause them to become wrinkled near the margins.

Effects of Growth Retardants

Wirwille and Mitchell (22) found that when plants were sprayed with

AMO-1618, a deeper green color developed and the leaves appeared to be thicker than those of nontreated plants. However, total solids in the treated plants were 11% less than in the control plants. Cathey (3) suggested that reduction in weight was primarily a result of reduction in stem length, since the number of nodes and weight of leaves of the treated plants were not affected. This suggests that growth retardants are active in the sub-apical meristem where cell division and cell elongation occur and not in the apical meristem where the leaves and nodes are produced. Riddell et al. (17) obtained similar data which indicated that although B-9 reduced plant height, the rate of leaf development was not affected.

Wirwille and Mitchell (22) showed that AMO-1618 delayed flowering of some plants by as much as ten days. Edgerton and Hoffman (5) found that pre-bloom spray applications of B-9 on apple trees delayed flowering but increased fruit set. Conversely, Stuart (19) suggested that applications of CCC on tomato plants induced earlier flowering.

Characteristics of Growth Retardants

AMO-1618 could, according to Cathey (3), persist in the soil for as much as ten years. He also found that CCC and B-9 would break down within three to four weeks. However, Martin and Williams (11) found that although Alar was degradated, the process was much slower than reported by Cathey. Martin and Williams (12) reported that it takes more than three months before much breakdown occurs.

CHAPTER III

METHODS AND MATERIALS

The objectives of these experiments were to obtain information on the growth response of leaf lettuce plants to foliar applications of three growth retardants. Determinations were made on the height, number of leaves, total weight and weight of the stems of each plant.

Chemicals used were Alar (B-9, B995), Cycocel (CCC) and AMO-1618.[1] Concentrations of each growth retardant used in the study were: (1) Alar at 1,250, 2,500, 5,000 and 10,000 ppm; (2) CCC at 295, 590 and 1,180 ppm; and (3) AMO at 250, 500, and 1,000 ppm. The materials were applied to three cultivars of leaf lettuce: (1) Grand Rapids; (2) Waldmann's Green and (3) Burk's Selection.

The materials were dissolved in water at their specified concentrations and a surfactant (Tween-20 at 3 mls per liter) added. It has been shown in earlier work, that growth retardants were so sufficiently mobile that a foliar spray could serve as an effective method of application. The materials were applied by means of a Beauty Mist hand atomizer with the leaves being throughly wetted.

Lettuce seeds were spot seeded in Jiffy strips and germinated under intermittent mist. When the seedlings were five to six weeks of age,

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[1]Alar (Succinic acid 2,2-dimethyl hydrazide) was furnished by Uniroyal Chemical Division of UNIROYAL, Inc., Naugatuck, Conn. Cycocel ((2-chloroethyl) trimethylammonium chloride) AMO-1618 (4-Hydroxyl-5-isopropyl-2-2-methylphenyl trimethyl ammonium chloride, 1-piperdine carboxylate)

they were transplanted to beds in trials one, two and four. Trials three and five were conducted in six inch pots. Foliar spray applications of each chemical were applied when the plants were at the two and eight leaf stage to determine if there were apparent advantages for a specific time of treatment. The crops were harvested six to seven weeks after transplanting and at harvest, the plants were cut, trimmed and cleaned in a manner similar to commercial handling. Data were taken at time of harvest.

Each crop was grown under normal greenhouse cultural practices of watering, fertilizing and spacing. The study was conducted in a greenhouse in which tomatoes were also being grown and as a result a night temperature of 62°F was above the optimum temperature for growing leaf lettuce and therefore, an ideal environment for study.

The experimental layout for trials one, two and four was a completely randomized block design. A plot was considered a treatment replication containing ten plants. Three replications of each treatment were used throughout in setting up these three trials. Measurements were taken from ten plants selected at random from each treatment.

The experimental layout for trials three and five was a completely random design with ten plants per treatment. These trials were in pots (one plant per pot) so that the randomization was easily conducted. Data were collected from all plants in these treatments.

Data on plant height, number of leaves per plant, total weight of plants and stem weight, taken from trials three, four and five were analyzed statistically. Duncan's New Multiple Range Test was used to separate the means within a trial.

Trial I: The first trial using the cultivar Grand Rapids, was

started November 16, 1967 when seed was sown and terminated with harvest 12 weeks later, January 30, 1968. The seedling were transplanted to beds December 11, 1967 and the treatments applied December 18. Since this trial was set up to be a screening test, varying concentrations of growth retardants were used. These consisted of: (1) Check (no chemical treatment); (2) Alar at 1,250 ppm; (3) Alar at 2,500 ppm; (4) Alar at 5,000 ppm; (5) CCC at 295 ppm; (6) CCC at 590 ppm; (7) CCC at 1,180 ppm; (8) AMO at 250 ppm; (9) AMO at 500 ppm and (10) AMO at 1,000 ppm.

Trial II: A second trial was started November 21 using the same leaf lettuce cultivar. The plants were transplanted to the beds December 27, and treated with growth retardants January 4, 1968. The treatments used were: (1) Check; (2) Alar at 10,000 ppm; (3) CCC at 590 ppm; (4) CCC at 1,180 ppm; (5) AMO at 500 ppm and (6) AMO at 1,000 ppm. This crop was harvested and data collected February 13, 1968.

From these two trials seven growth retardant treatments were selected for further study. The treatments excluding the check were: (1) Alar at 1,250 ppm; (2) Alar at 2,500 ppm; (3) CCC at 295 ppm; (4) CCC at 590 ppm; (5) CCC at 1,180 ppm; (6) AMO at 250 ppm and (7) AMO at 500 ppm.

Trial III: Two cultivars of leaf lettuce, Grand Rapids and Waldmann's Green, were used in this trial. Seeds of each cultivar were sown December 22, 1967 and one seedling transplanted per pot February 10, 1968. The seven chemical treatments listed above, plus a check, were assigned at random by pot and the plants treated March 2. The plants were harvested and data collected March 26.

Trial IV: The fourth trial, using Burk's Selection, was seeded January 2, 1968. The plants were transplanted to beds February 6. The

eight standard treatments were applied March 15 and the crop harvested March 30.

Trial V: This trial was identical with Trial III, except for the dates and age at the time of application. Seeds of the cultivars Grand Rapids and Waldmann's Green were sown January 8 and the seedlings transplanted to pots February 10. Treatments were applied March 2 and the plants harvested April 11.

In addition to the above trials, seeds of each cultivar were germinated, seedlings transplanted to beds, treated with growth retardants and allowed to mature to determine when seed stalk development would occur. Burk's Selection was seeded January 2, transplanted February 6, and treated March 15. The Grand Rapids and Waldmann's Green cultivars were seeded February 17 and transplanted March 28. Two plots of each cultivar were treated with Alar at 1,250 ppm, CCC at 295 ppm and AMO at 250 ppm when the plants were at the two leaf stage. The remaining plots were treated on April 13 with the previously described materials.

CHAPTER IV

RESULTS

Plant growth response to varying concentrations of Alar, CCC and AMO is variable. Significant differences were found among the growth retardants and their various concentrations on all three cultivars of leaf lettuce studied. The results of these tests suggest that certain growth retardant treatments may have a desirable effect on leaf lettuce production by lengthening the seasonal production cycle which is now limited to winter months in Oklahoma.

Trial I: Figure 1 shows that in general, increasing concentrations of growth retardants reduced plant height of Grand Rapids as compared to that attained by the checks. However, all treatments, regardless of concentration used, produced marketable leaf lettuce. All of the retardants increased the number of leaves per plant, Figure 2. This was an unexpected response that merits further study. The effect of the growth retardants on the number of leaves per pound are in Figure 3. The measured responses were impressive due to the fact that the treated plants were much smaller but proportionally had a greater number of leaves. As shown in Figure 4, Alar and AMO treatments reduced total weight when compared to the check, while the CCC treatments increased total weight.

Trial II: The effect of spraying Grand Rapids plants with Alar, CCC and AMO on plant height is shown in Figure 5. High concentrations

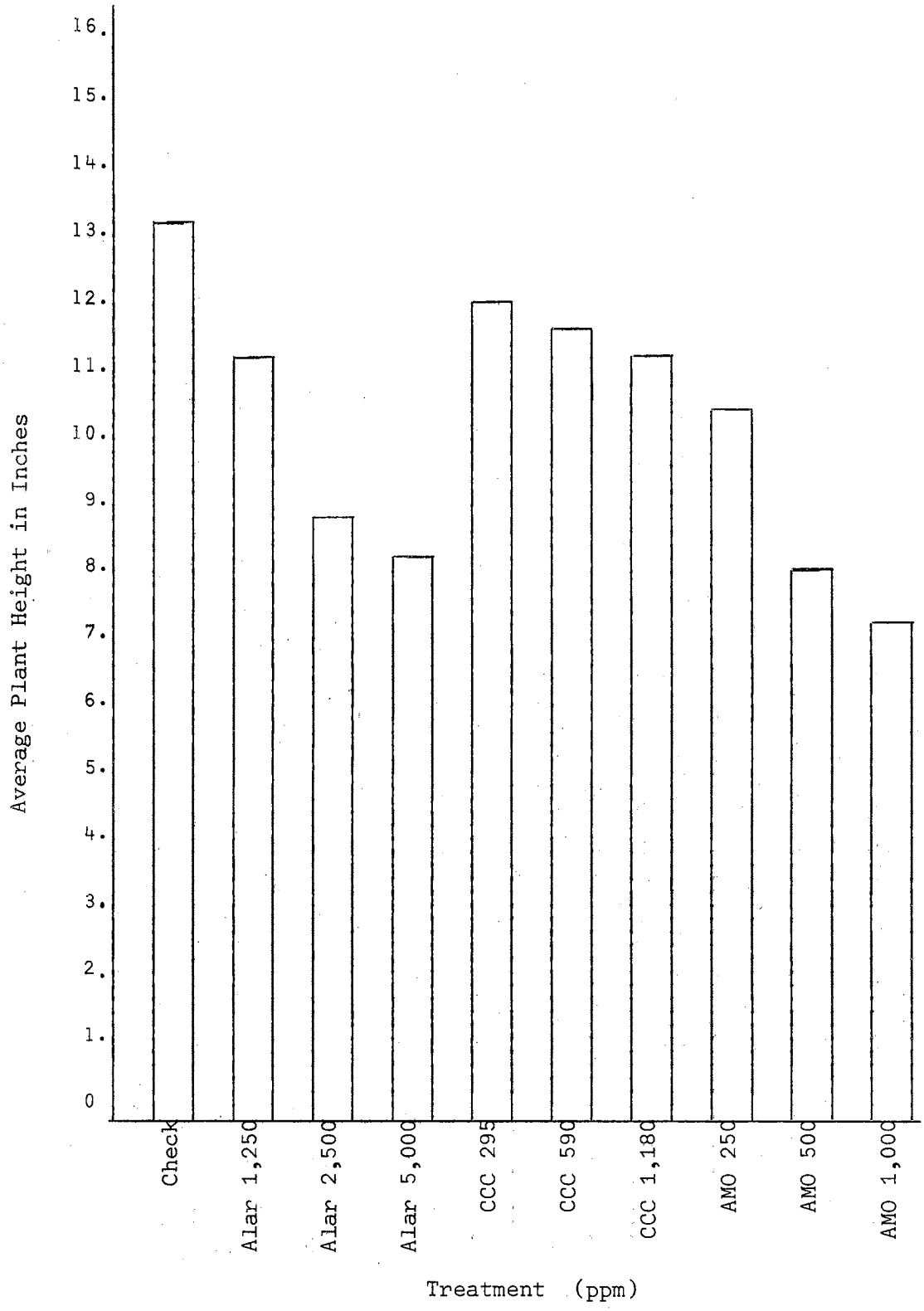


Figure 1. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Average Plant Height of Grand Rapids Leaf Lettuce Plants (Trial I Transplanted 11 December, Treated 18 December, Harvested 30, January 1968).

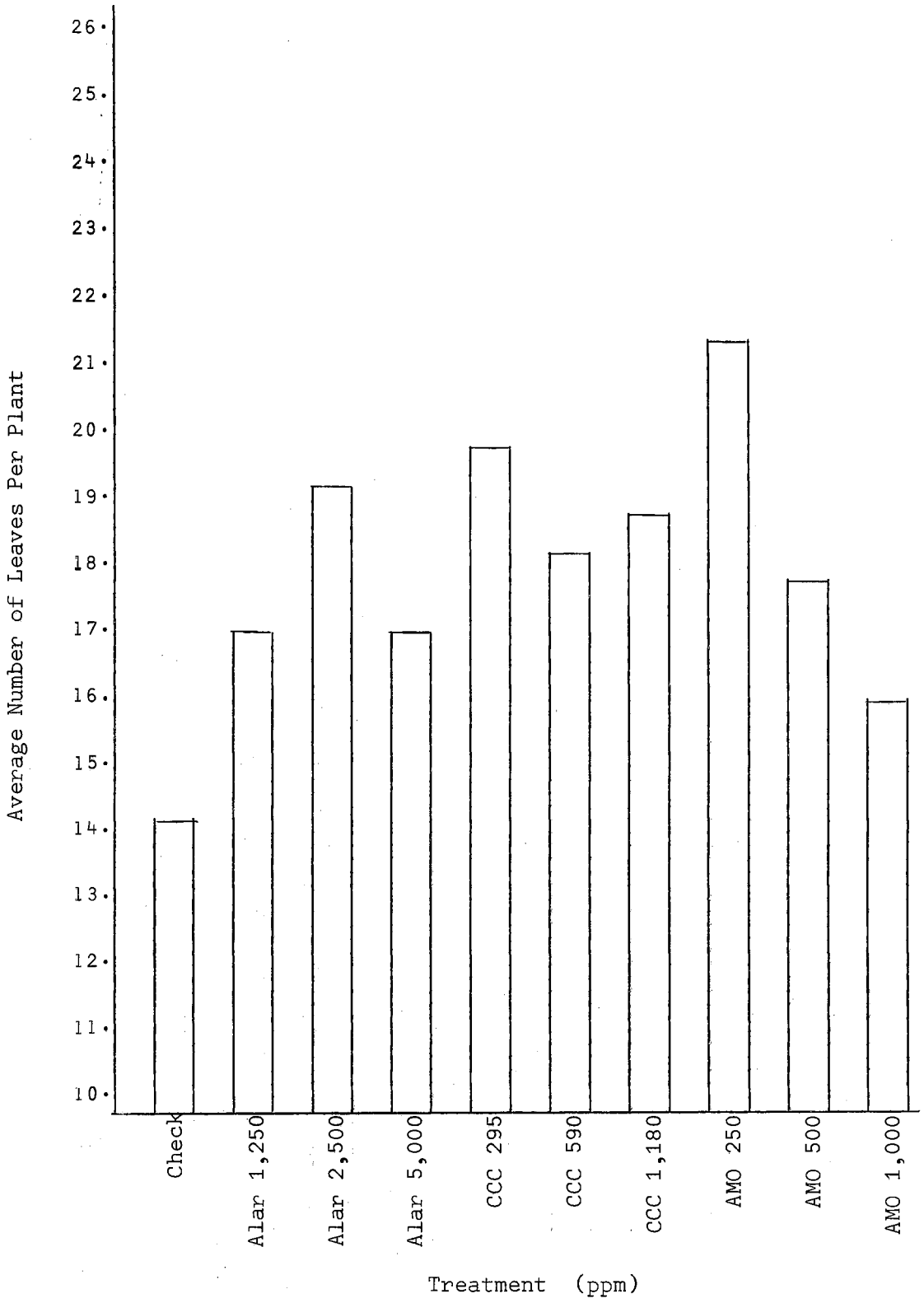
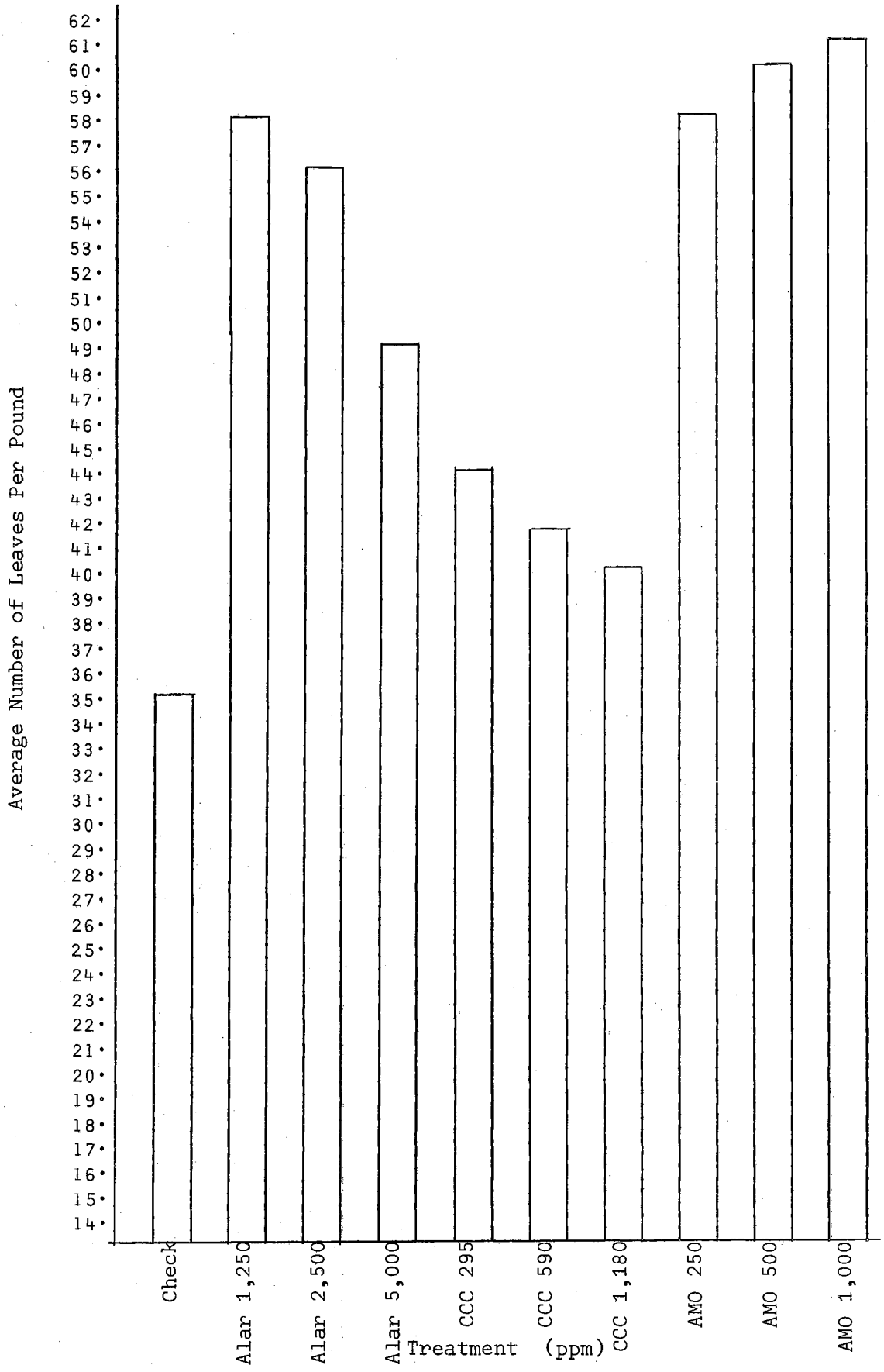


Figure 2. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Number of Leaves per Plant of Grand Rapids Leaf Lettuce Plants (Trial I Transplanted 11 December, Treated 18 December, Harvested 30 January 1968).

Figure 3. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Average Number of Leaves Per Pound of Grand Rapids Leaf Lettuce Plants (Trial I, Transplanted 11 December, Treated 18 December, Harvested 30 January 1968).


Average Number of Leaves Per Pound
62
61
60
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46
45
44
43
42
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18
17
16
15
14
Check
Alar 1,250
Alar 2,500
Alar 5,000
CCC 295
CCC 590
CCC 1,180
AMO 250
AMO 500
AMO 1,000
Treatment (ppm)

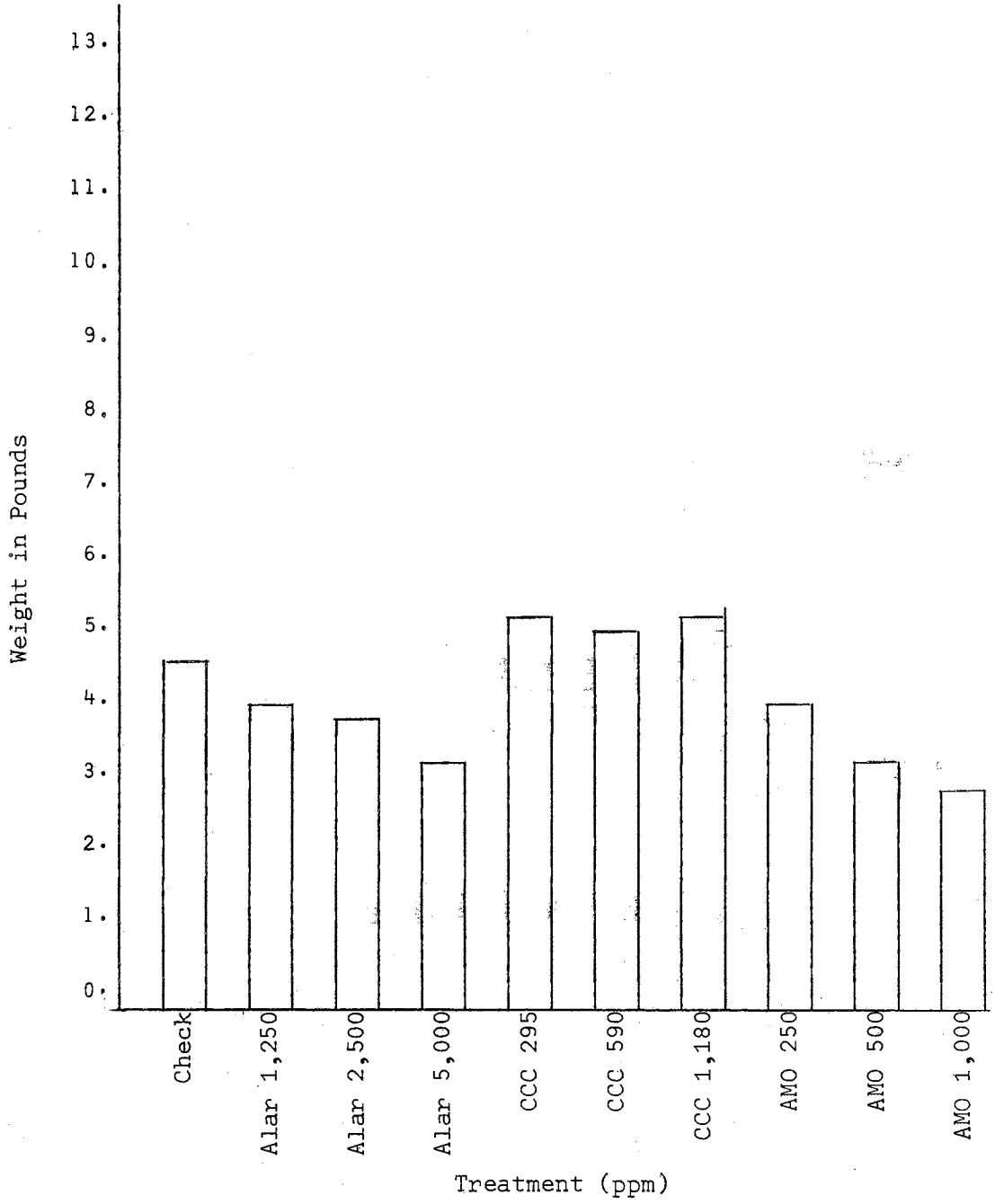

Figure 4. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Grand Rapids Leaf Lettuce Plants with Reference to Weight* (Trial I, Transplanted 11 December, Treated 18 December, Harvested 30 January 1968).

*Weight of 10 Plants.

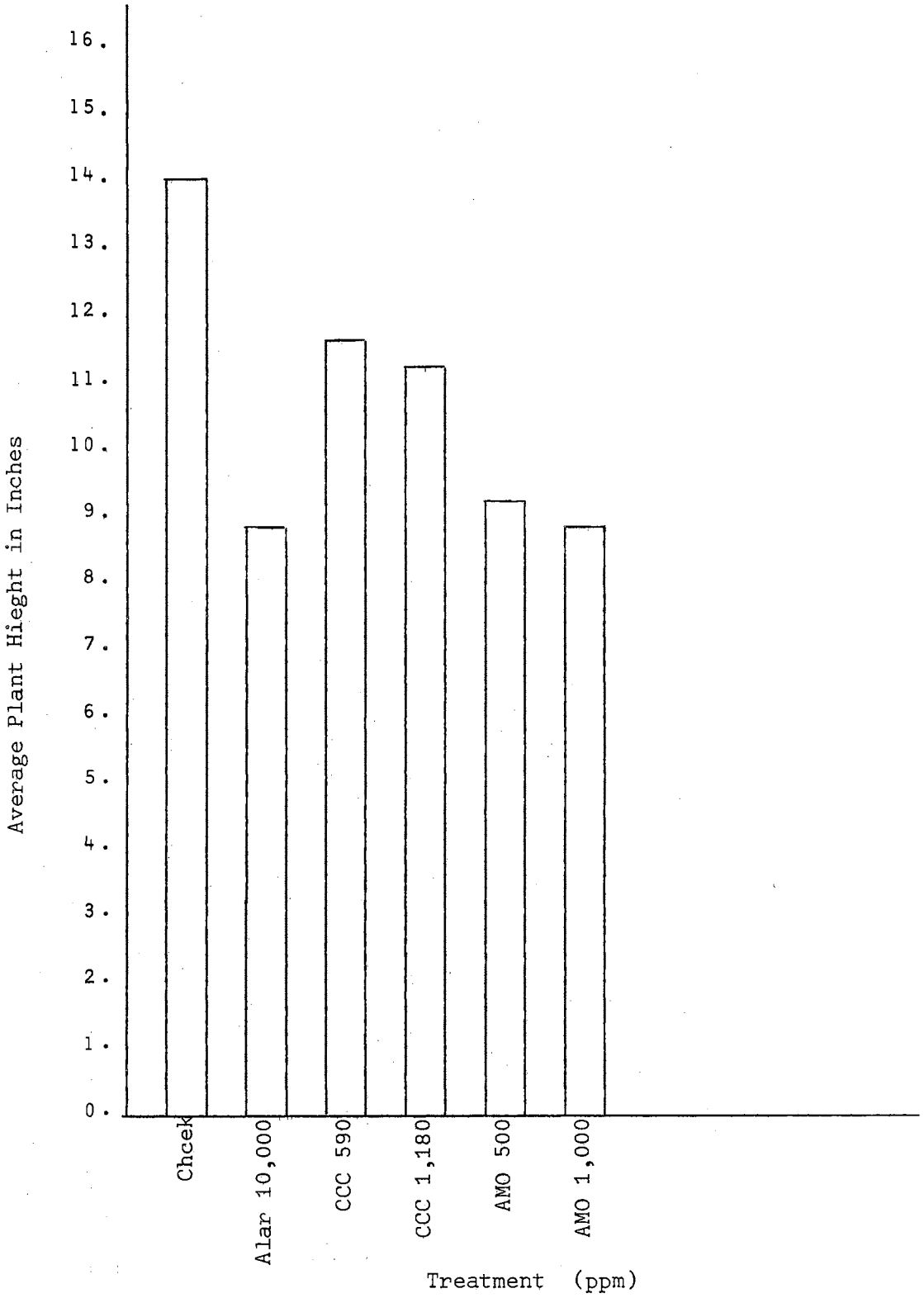

Figure 5. Effect of Spray Applications of Various Concentrations of Alar, CCC, and AMO on Average Plant Height of Grand Rapids Leaf Lettuce Plants (Trial II, Transplanted 27 December, 1967, Treated 4 January, 1968, Harvested 13 February, 1968).

of the retardants, in general, reduced plant height more than low concentrations. The differences in height between the check and treated plants seemed in part due to a shortening of internodes since the leaves of the treated plants were normal in size and shape. The number of leaves per plant was increased, Figure 6. In addition the number of leaves per pound, Figure 7, was increased in all chemical treatments with the exception of CCC at 590 ppm. The differences however, were not as impressive as for Trial I. Figure 8 shows the effect of growth retardants on total weight. In this instance, all but one chemical treatment stimulated total weight.

Concentrations of growth retardants for the remaining trials (three, four and five) were selected on the basis of their ability to restrict plant height and increase the number of leaves per plant without the total weight being drastically reduced.

Duncan's New Multiple Range Test was performed on certain data (plant height, number of leaves per plant, total weight and stem weight) in Trials III, IV and V to indicate significant differences among the means.[1]

Trial III a: The effect of selected concentrations of Alar, CCC and AMO on plant height of Grand Rapids are shown in Figure 9. It was found that plants from all of the chemical treatments were significantly shorter than those from the check. The number of leaves per plant of

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[1]These treatments are labeled as to their significance by having letters above the treatments. If the letters are alike, the treatments are a homogenous subset of which no pair may differ by more than the shortest significant range for a subset of that size. If the letters are different the treatments differ by more than the shortest significant range for a subset of that size.

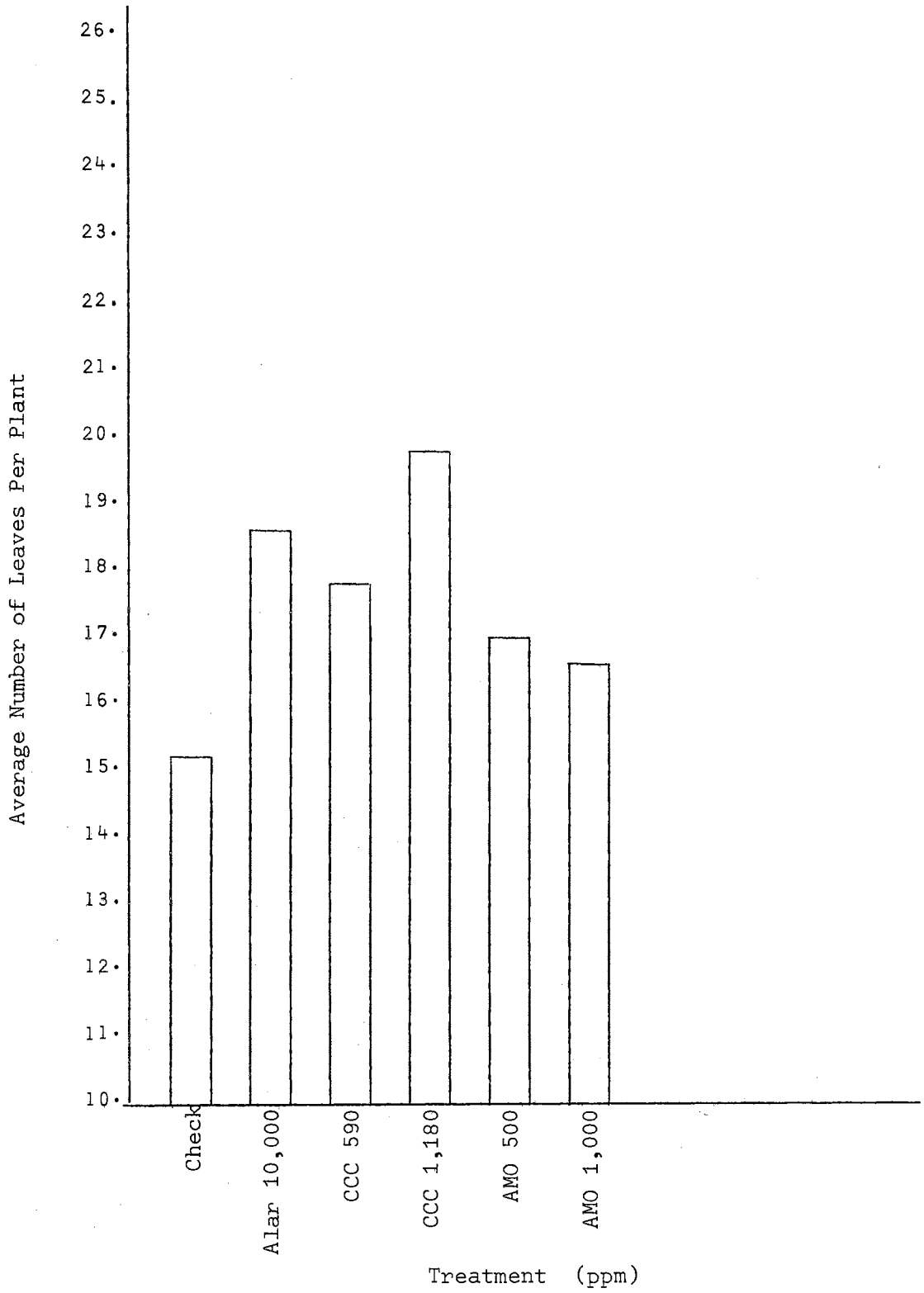
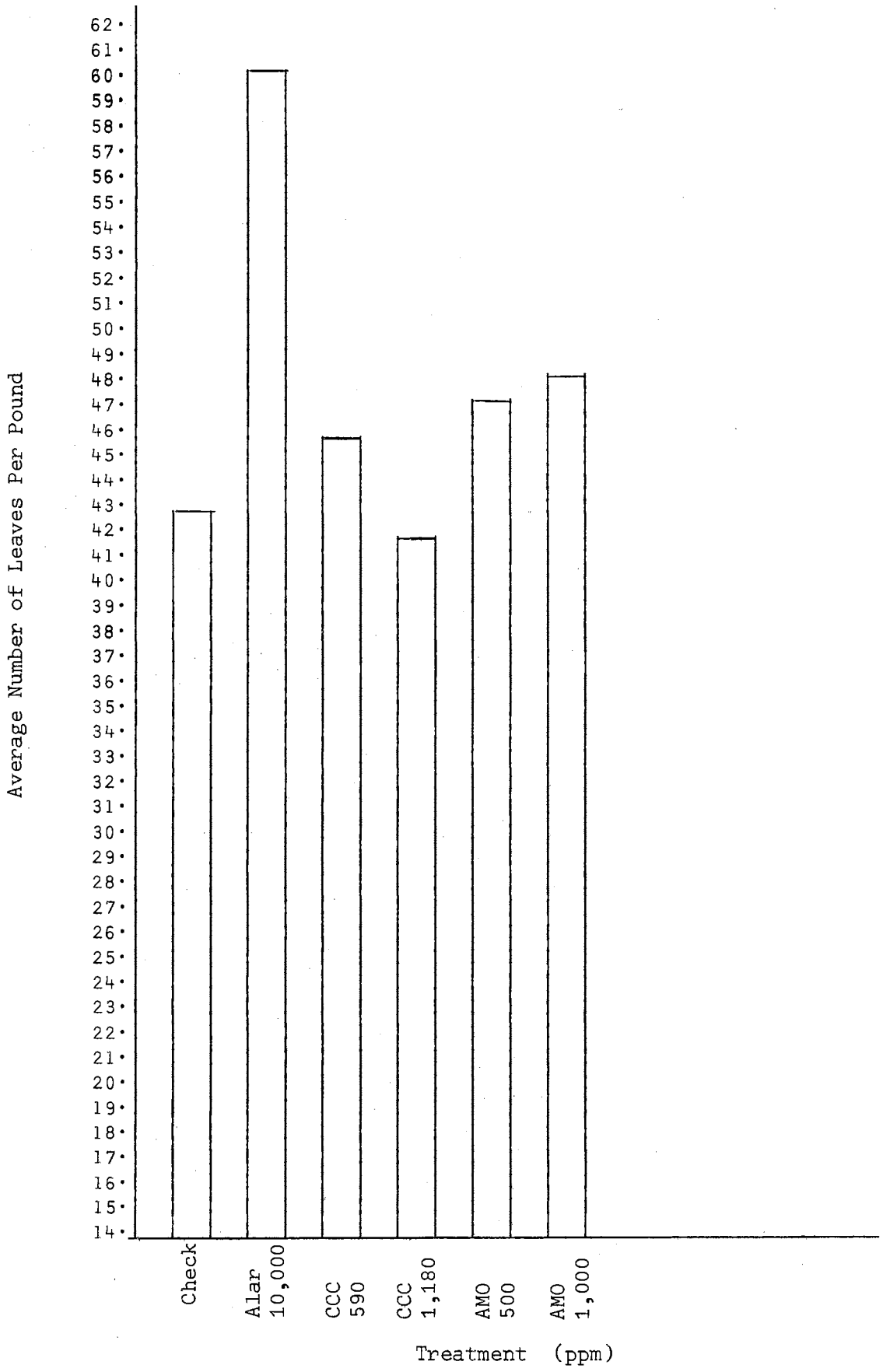


Figure 6. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Average Number of Leaves Per Plant of Grand Rapids Leaf Lettuce Plants (Trial II, Transplanted 27 December, 1967, Treated 4 January, 1968, Harvested 13 February, 1968).

Figure 7. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Average Number of Leaves Per Pound of Grand Rapids Leaf Lettuce Plants (Trial II, Transplanted 27 December, 1967, Treated 4 January, 1968, Harvested 13 February, 1968).


Average Number of Leaves Per Pound
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
Check
Alar 10,000
CCC 590
CCC 1,180
AMO 500
AMO 1,000
Treatment (ppm)

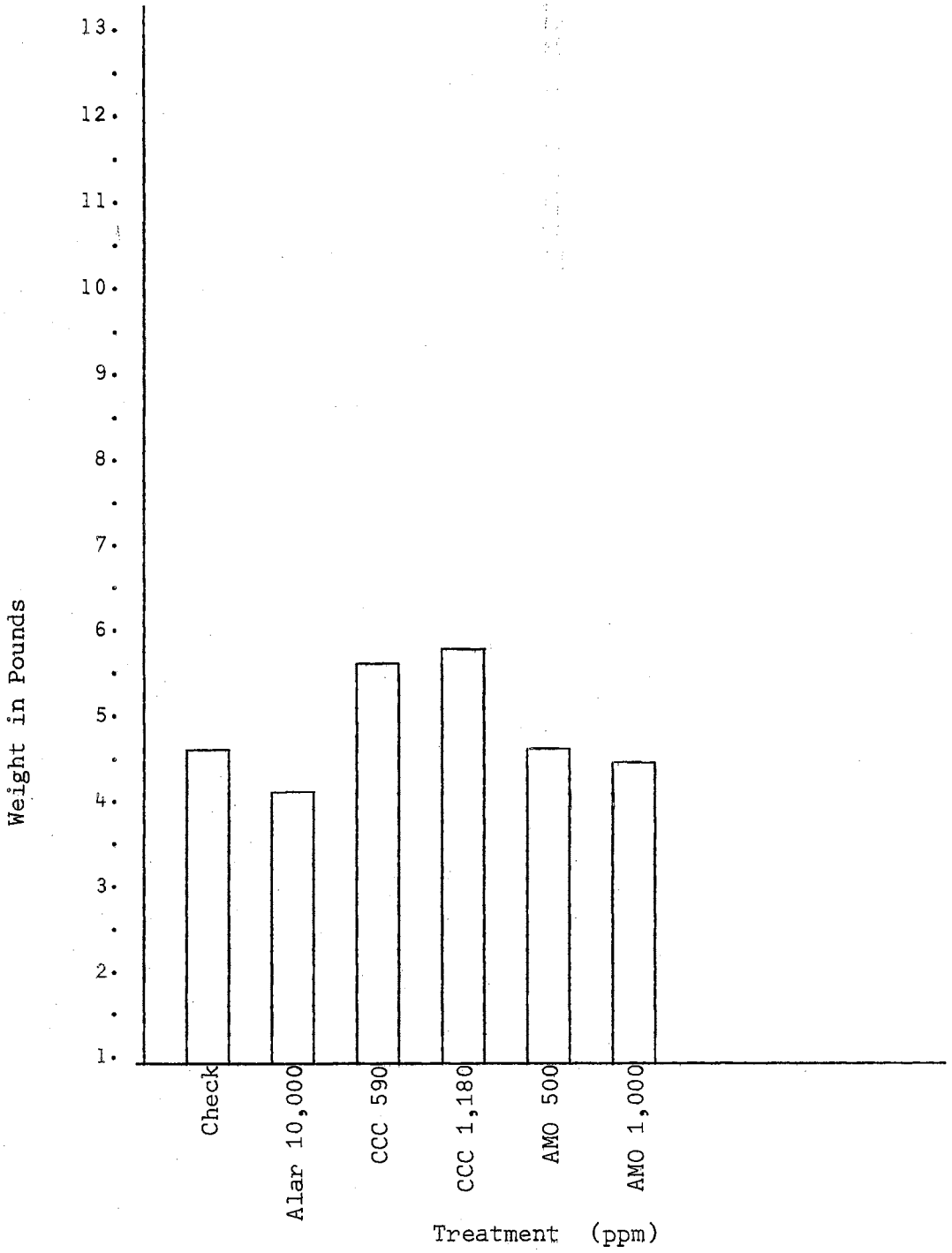


Figure 8. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Grand Rapids Leaf Lettuce Plants with Reference to Weight* (Trial II, Transplanted 27 December 1967, Treated 4 January 1968, Harvested 13 February 1968).

*Weight of 10 Plants.

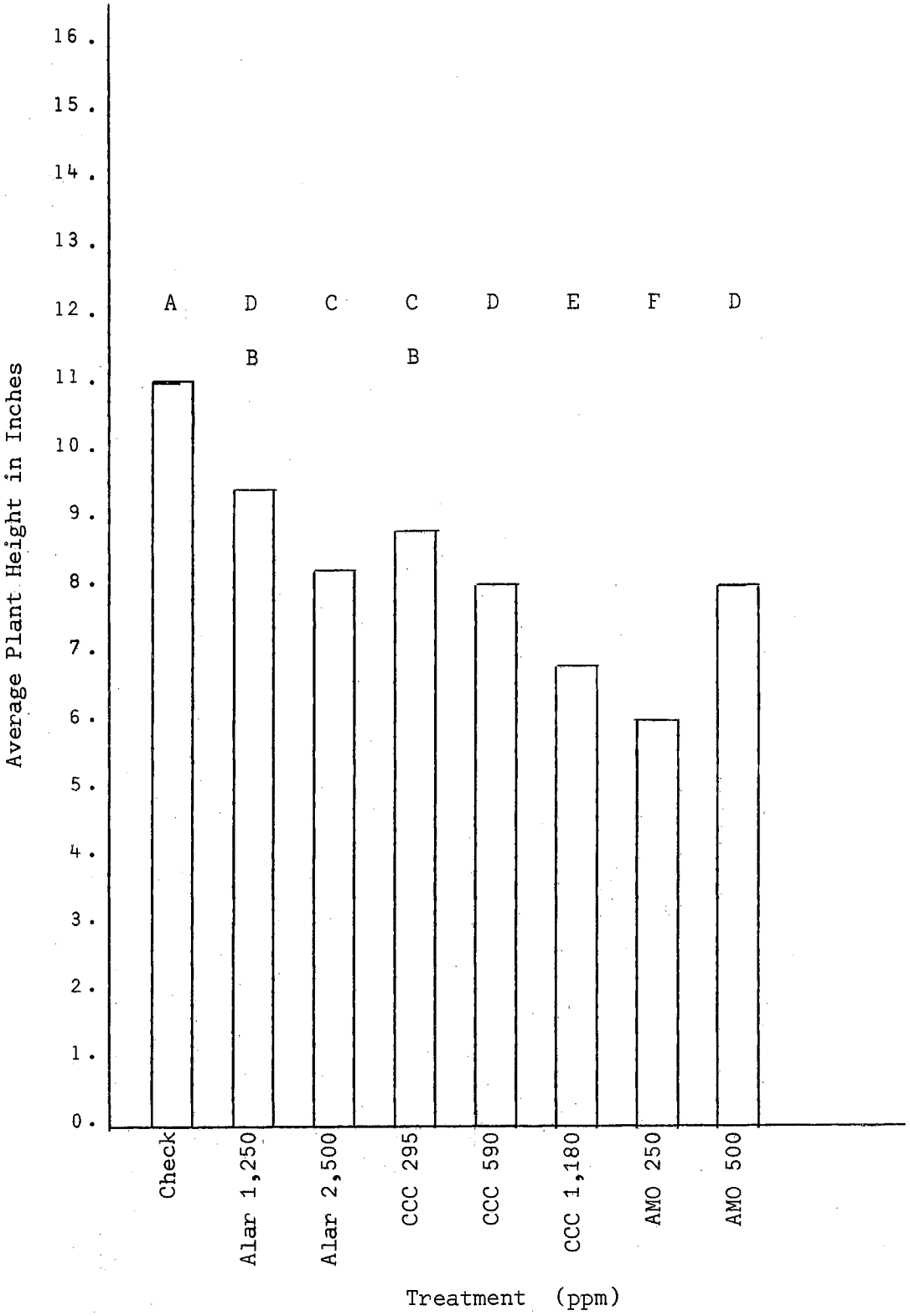


Figure 9. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Height of Grand Rapids Leaf Lettuce Plants (Trial IIIa, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 26 March 1968).

the chemically treated plants were significantly greater than the check plants as indicated in Figure 10. In Figure 11, the increase in the number of leaves per pound can be noted for all chemical treatments. It is well to note that although differences in weight between treatments do exist, Figure 12, they are not significant. The effects of the growth retardants on weight of leaves are shown in Figure 13. The weight of leaves produced by the treated plants was greater than the check plants with the exception of Alar at 2,500 ppm and AMO at 250 ppm, even though the check plants weighed more initially. The reason for this occurrence is shown in Figure 14. The weight of stems from the plants treated with growth retardants was significantly less than the weight of stems from the check plants.

Trial III b: Figure 15 shows the effect of applications of various concentrations of growth retardants on plant height of the cultivar Waldmann's Green. With the exception of CCC at 590 ppm, all treatments significantly shortened the plants. Treated plants produced more leaves than did the check plants. However, Figure 16, two treatments, CCC at 295 ppm and CCC at 590 ppm, did not give a significant increase in the number of leaves per plant. In Figure 17, the effect of spray applications of Alar, CCC and AMO on the number of leaves per pound is shown. CCC at 295 ppm was the only chemical treatment that did not increase the number of leaves per pound. All of the treatments in this trial, except AMO at 250 ppm, increased plant weight. These results are reported in Figure 18. There were no significant differences in weight. Figure 19 shows that the leaf weight was increased only slightly by treatment with growth retardants. Again this was found to be the result of a reduction in stem weight as shown in Figure 20. CCC at 295 ppm was

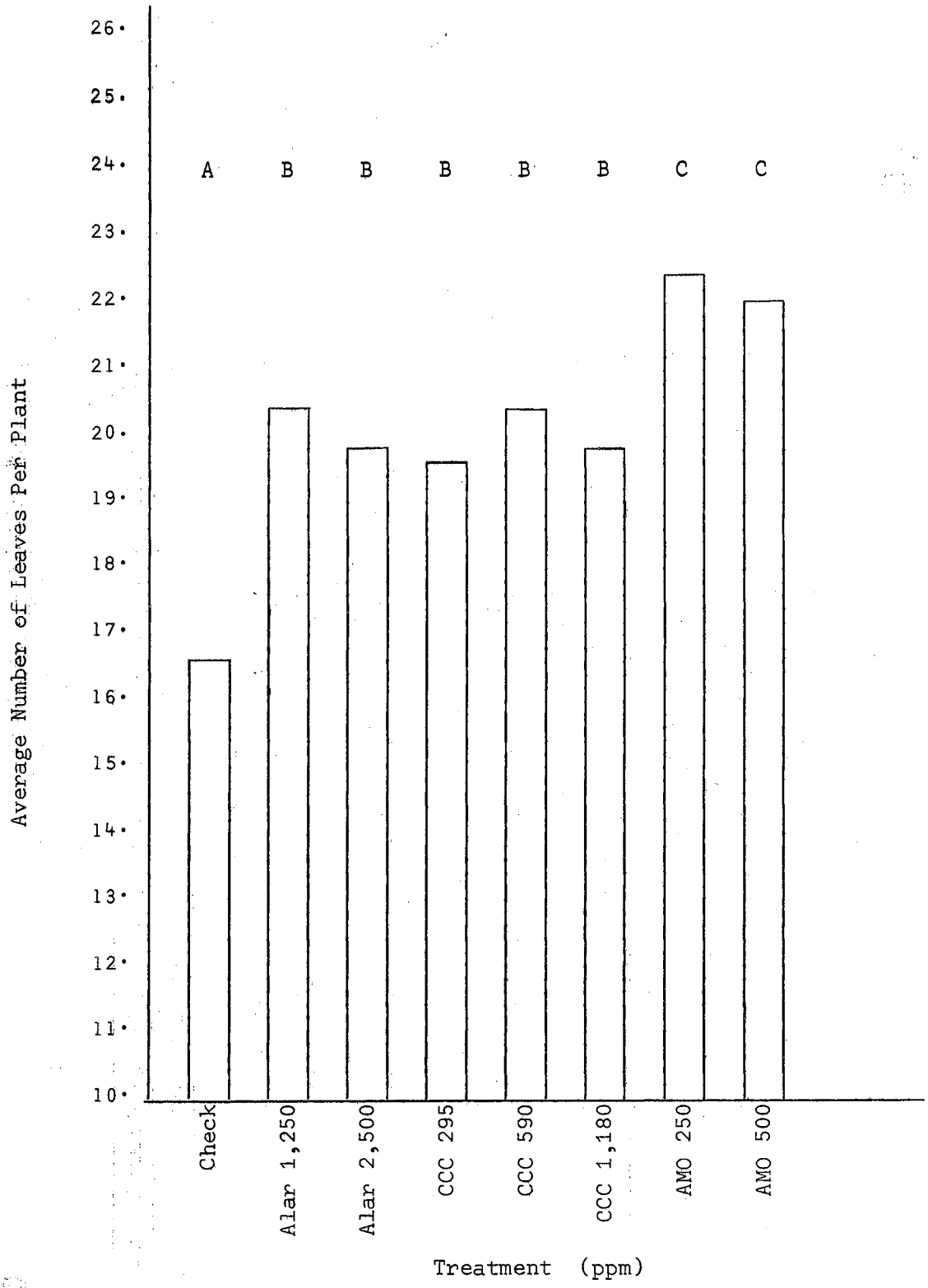
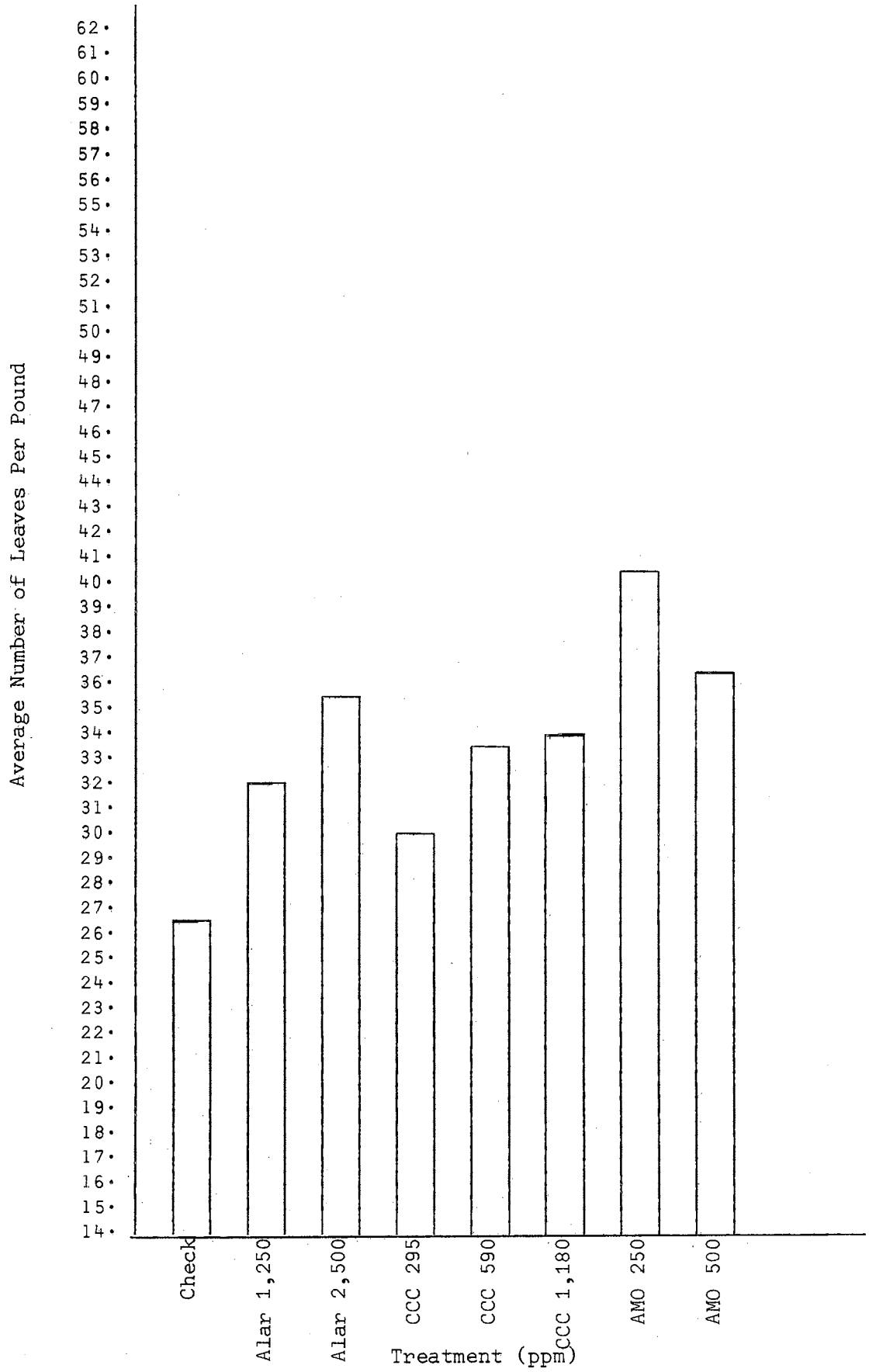


Figure 10. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Number of Leaves Per Plant of Grand Rapids Leaf Lettuce Plants (Trial III a, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 26 March 1968).

Figure 11. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Number of Leaves Per Pound of Grand Rapids Leaf Lettuce Plants (Trial III a, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 26 March 1968).


Average Number of Leaves Per Pound
62.
61.
60.
59.
58.
57.
56.
55.
54.
53.
52.
51.
50.
49.
48.
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19.
18.
17.
16.
15.
14.
Check
Alar 1,250
Alar 2,500
CCC 295
CCC 590
CCC 1,180
AMO 250
AMO 500
Treatment (ppm)

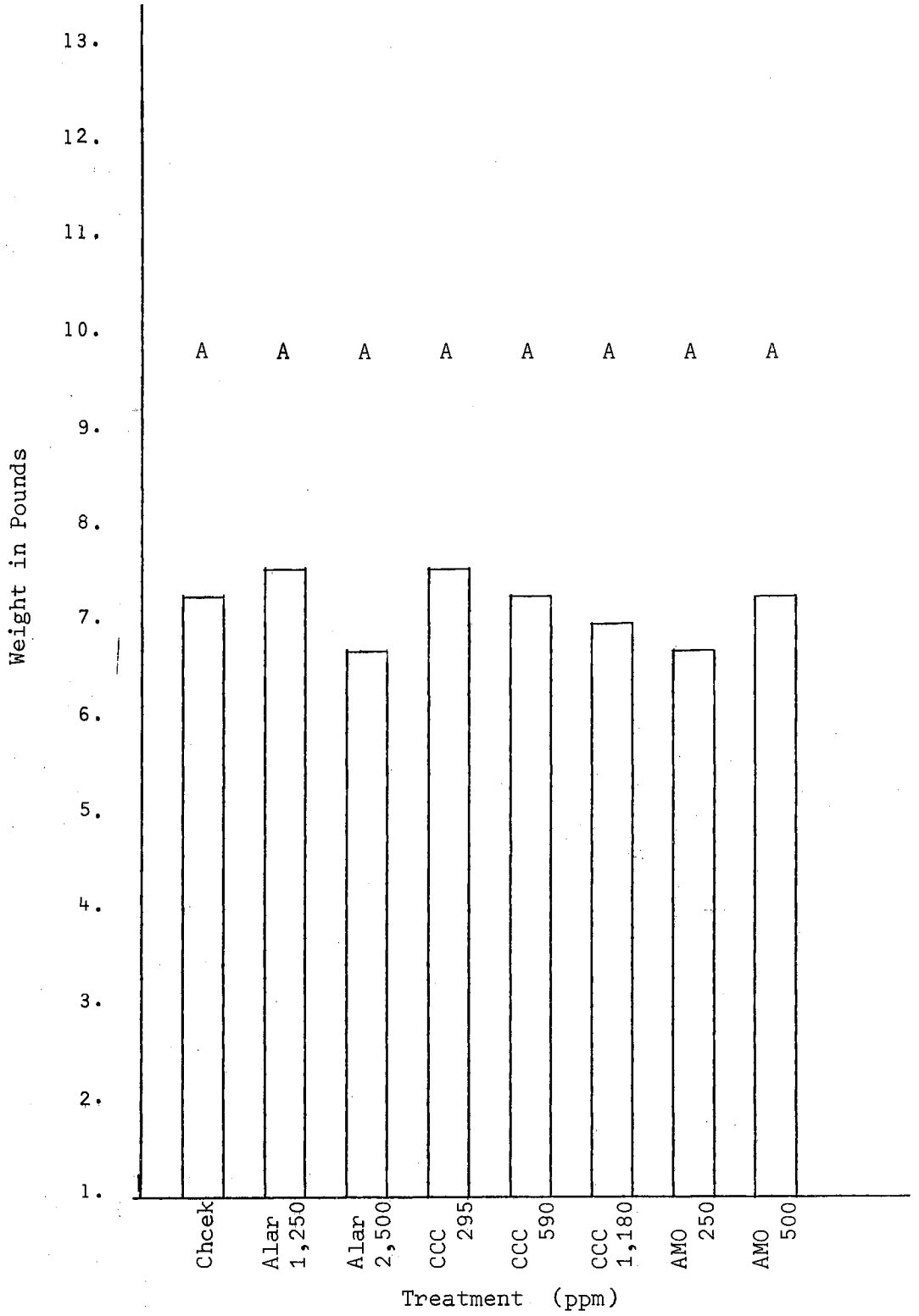


Figure 12. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Grand Rapids Leaf Lettuce Plants with Reference to Weight* (Trial III a, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 26 March 1968).

*Weight of 10 plants.

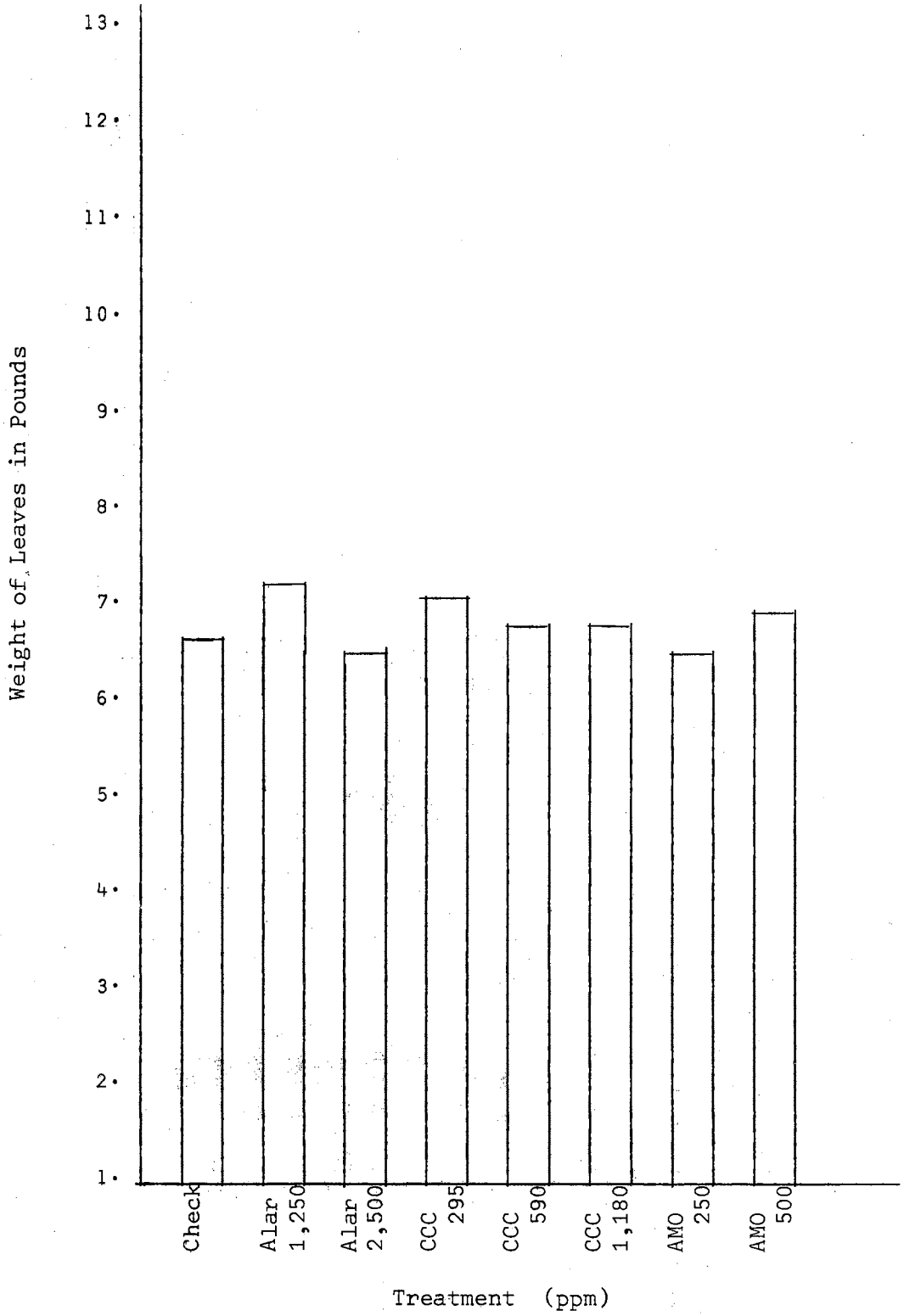
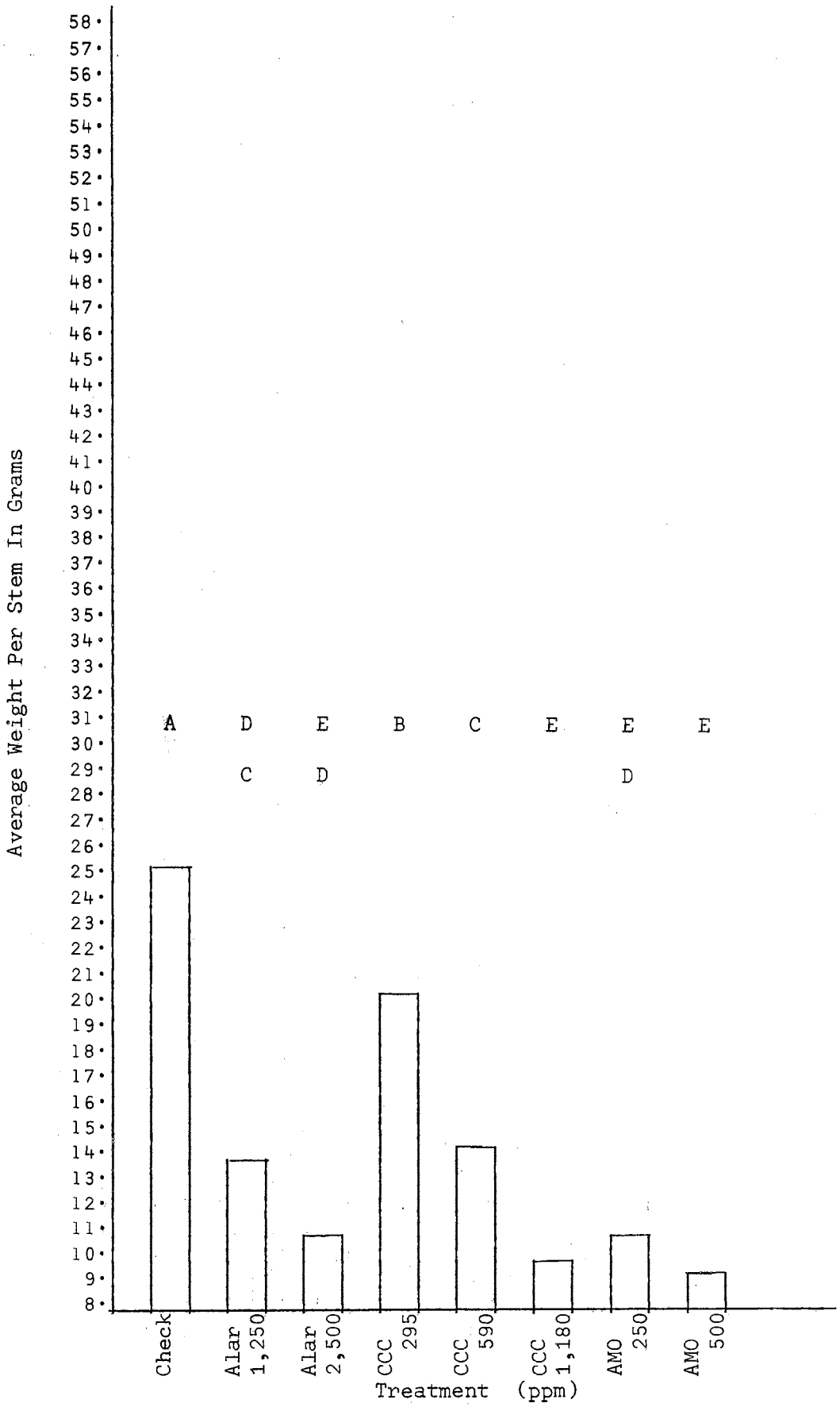


Figure 13. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Weight of Leaves* of Grand Rapids Leaf Lettuce Plants (Trial III a, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 26 March 1968).

*Leaves of 10 plants.

Figure 14. Effect of Spray Applications of Various Concentrations of Alar,CCC and AMO on the Average Weight Per Stem of Grand Rapids Leaf Lettuce Plants (Trial III a, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 26 March 1968).


Average Weight Per Stem In Grams
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
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22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
A
D
C
E
D
B
C
E
E
D
E
Check
Alar 1,250
Alar 2,500
CCC 295
CCC 590
CCC 1,180
AMO 250
AMO 500
Treatment (ppm)

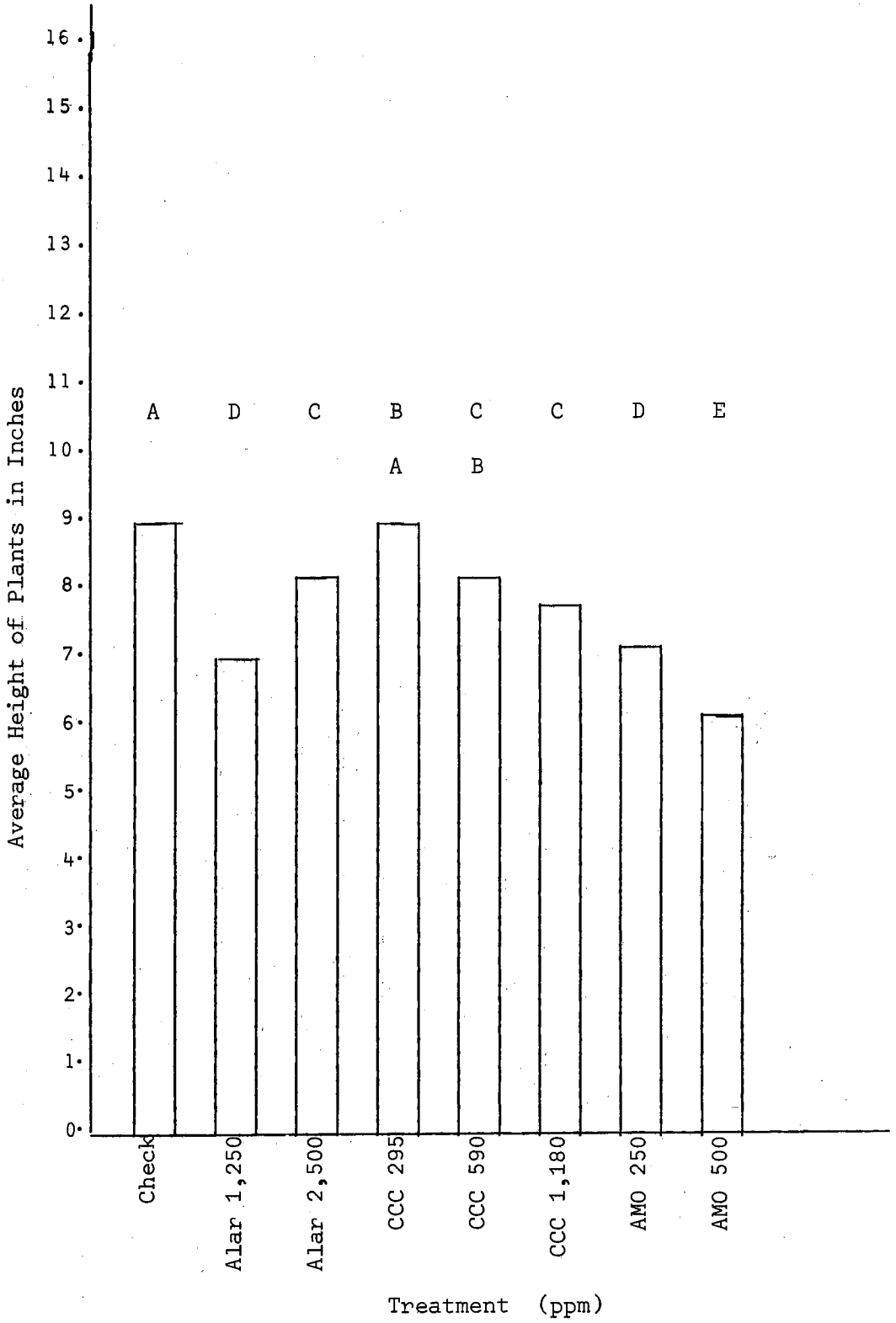


Figure 15. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Height of Waldmann's Green Leaf Lettuce Plants (Trial III b, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 26 March 1968).

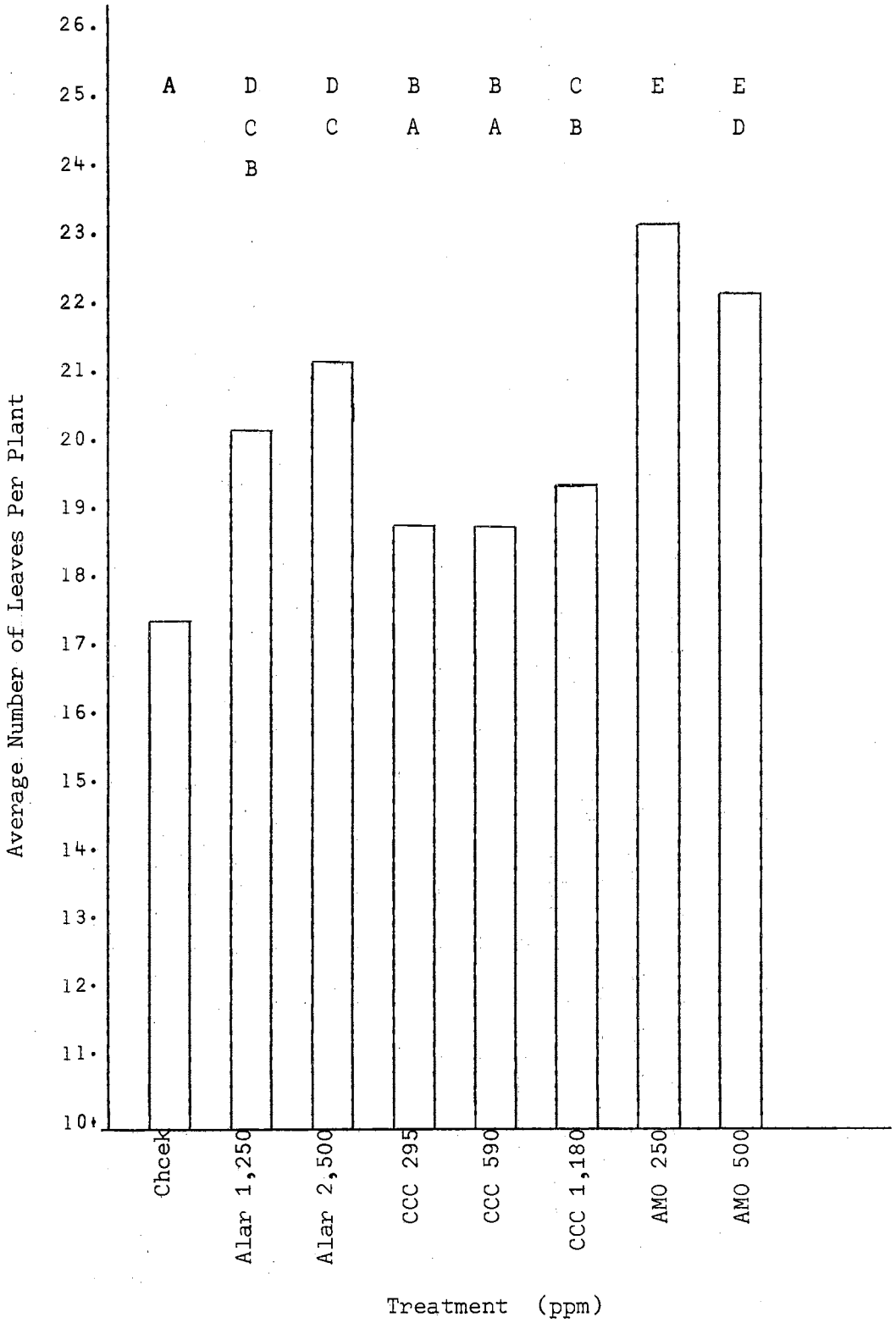
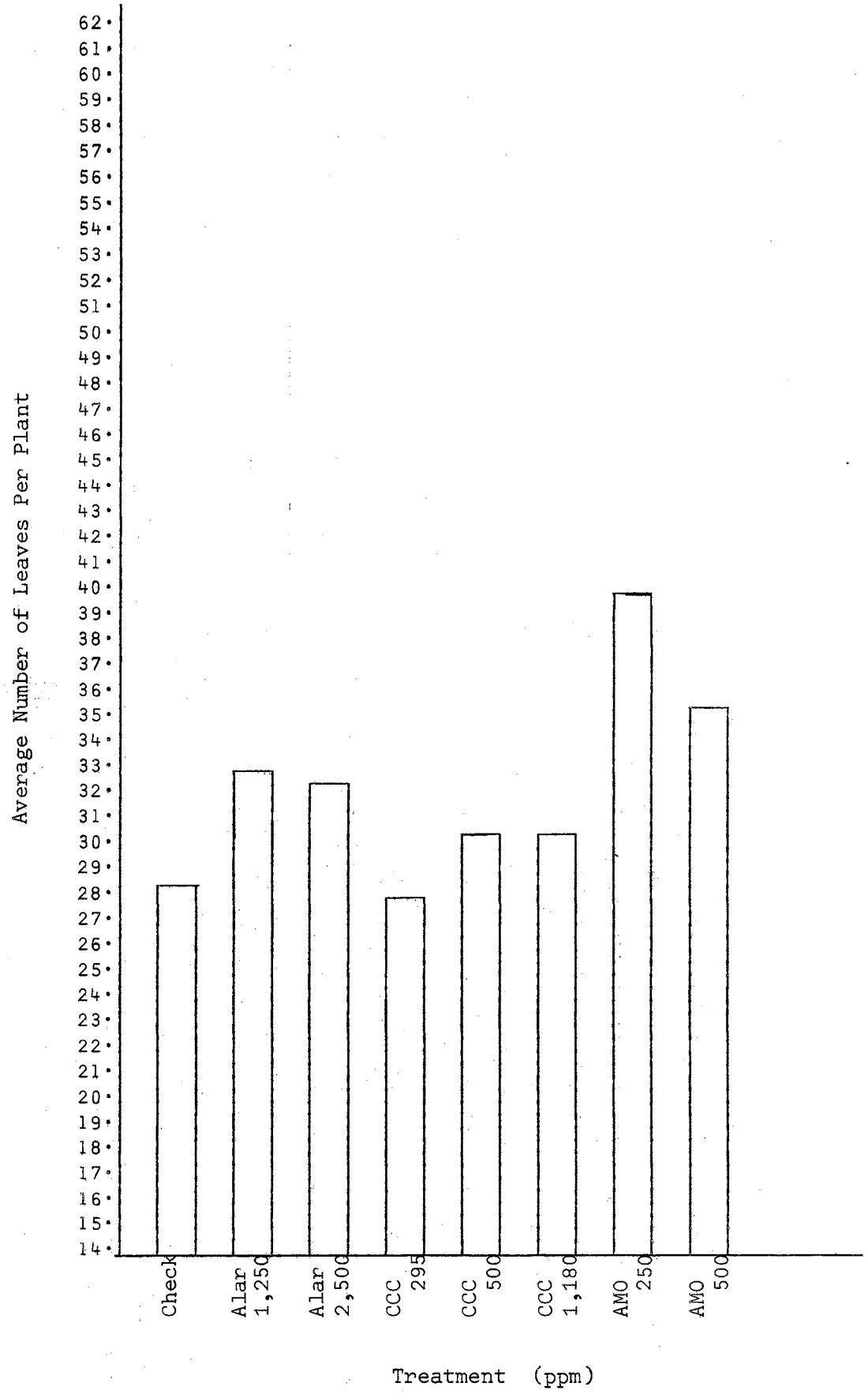


Figure 16. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Number of Leaves Per Plant of Waldmann's Green Leaf Lettuce Plants (Trial III b, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 26 March 1968).

Figure 17. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Number of Leaves Per Pound of Waldmann's Green Leaf Lettuce Plants (Trial III b, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 26 March 1968).


Average Number of Leaves Per Plant
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
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34
33
32
31
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29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
Check
Alar 1,250
Alar 2,500
CCC 295
CCC 500
CCC 1,180
AMO 250
AMO 500
Treatment (ppm)

Figure 18. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Waldmann's Green Leaf Lettuce Plants with Reference to Weight* (Trial III b, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 26 March 1968).

*Weight of 10 plants.

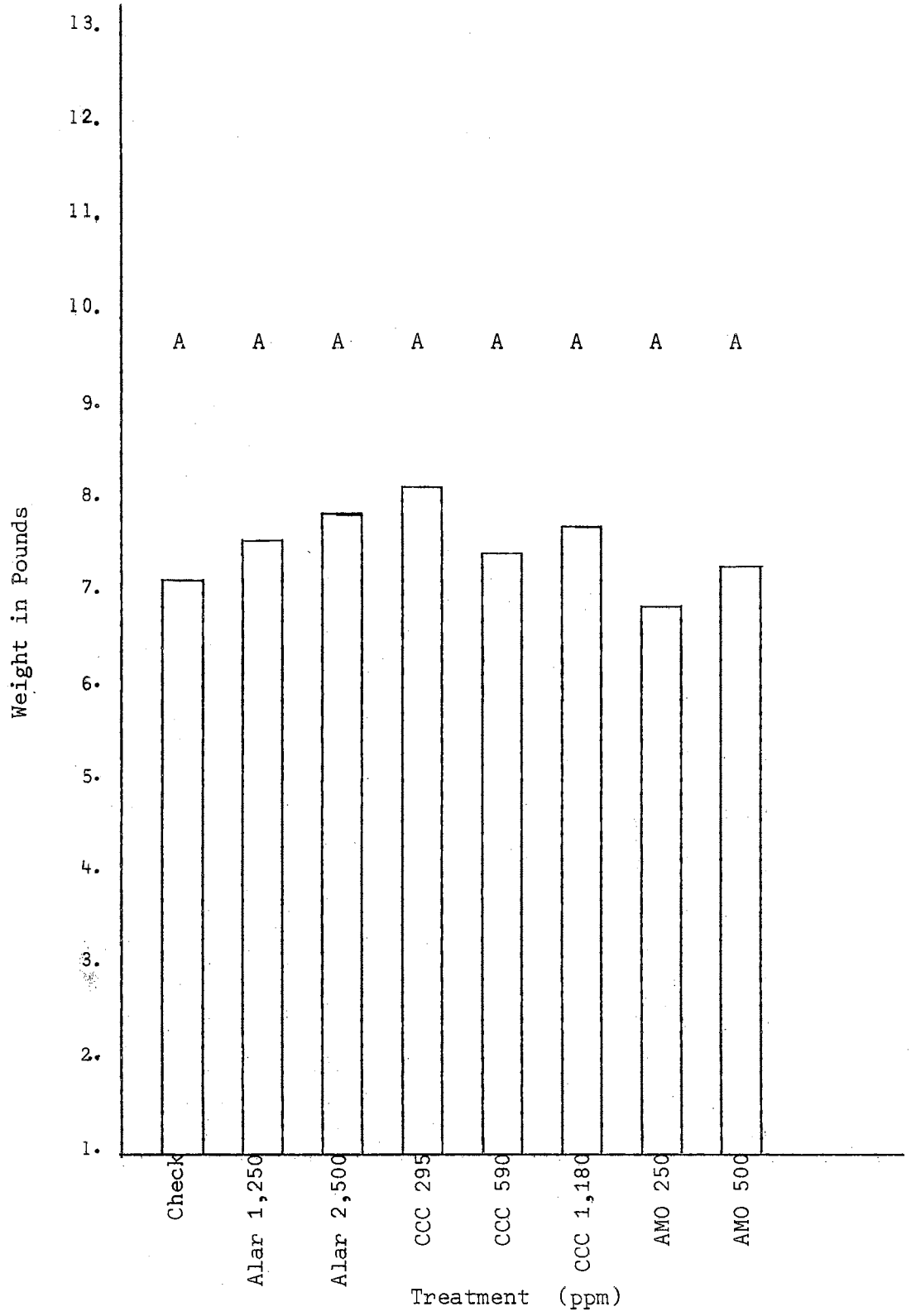

13.
12.
11.
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
Weight in Pounds
A A A A A A A A
Check
Alar 1,250
Alar 2,500
CCC 295
CCC 590
CCC 1,180
AMO 250
AMO 500
Treatment (ppm)

Figure 19. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Weight of Leaves* on Waldmann's Green Leaf Lettuce Plant (Trail III b, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 26 March 1968).

*Leaves of 10 plants.

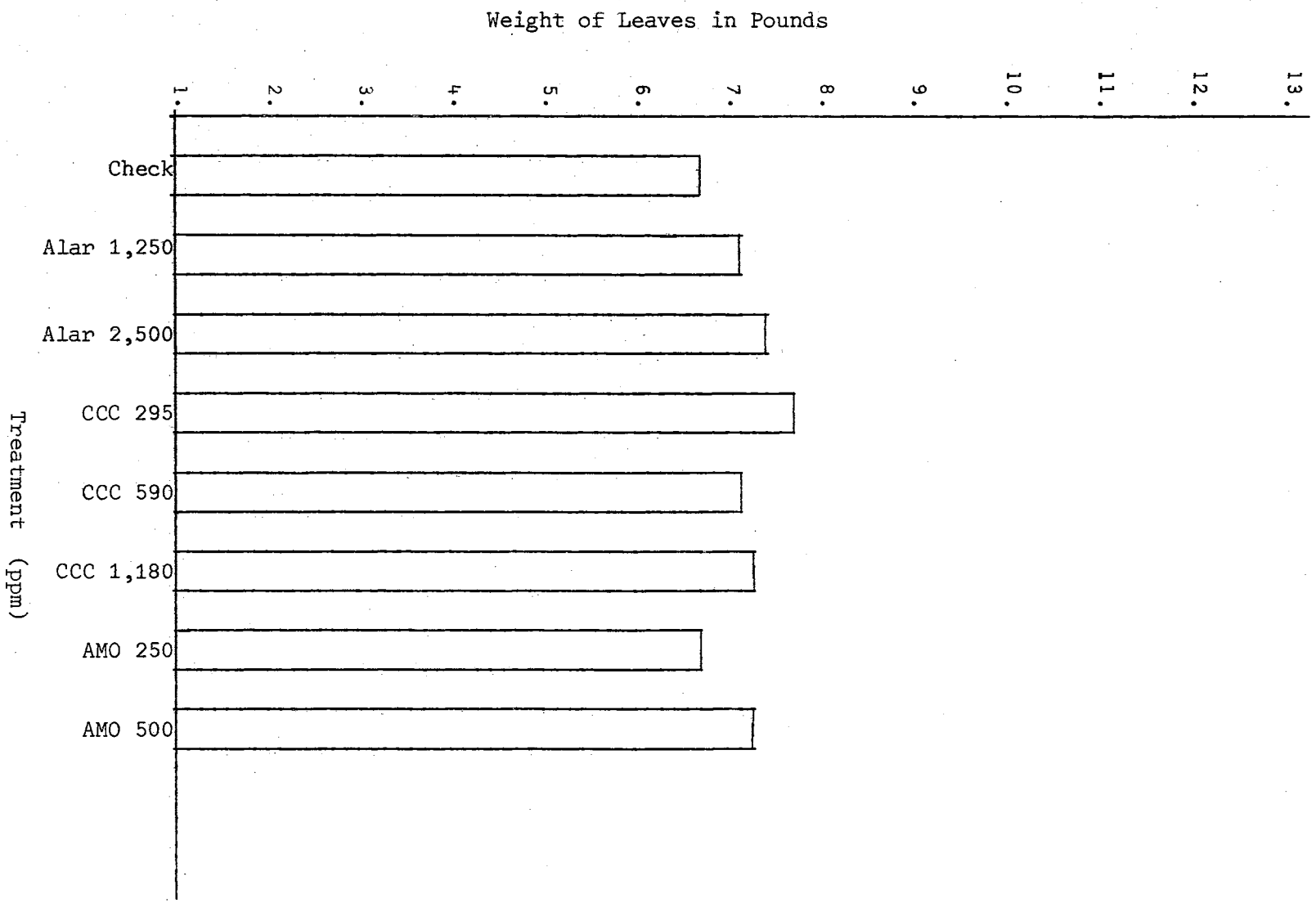
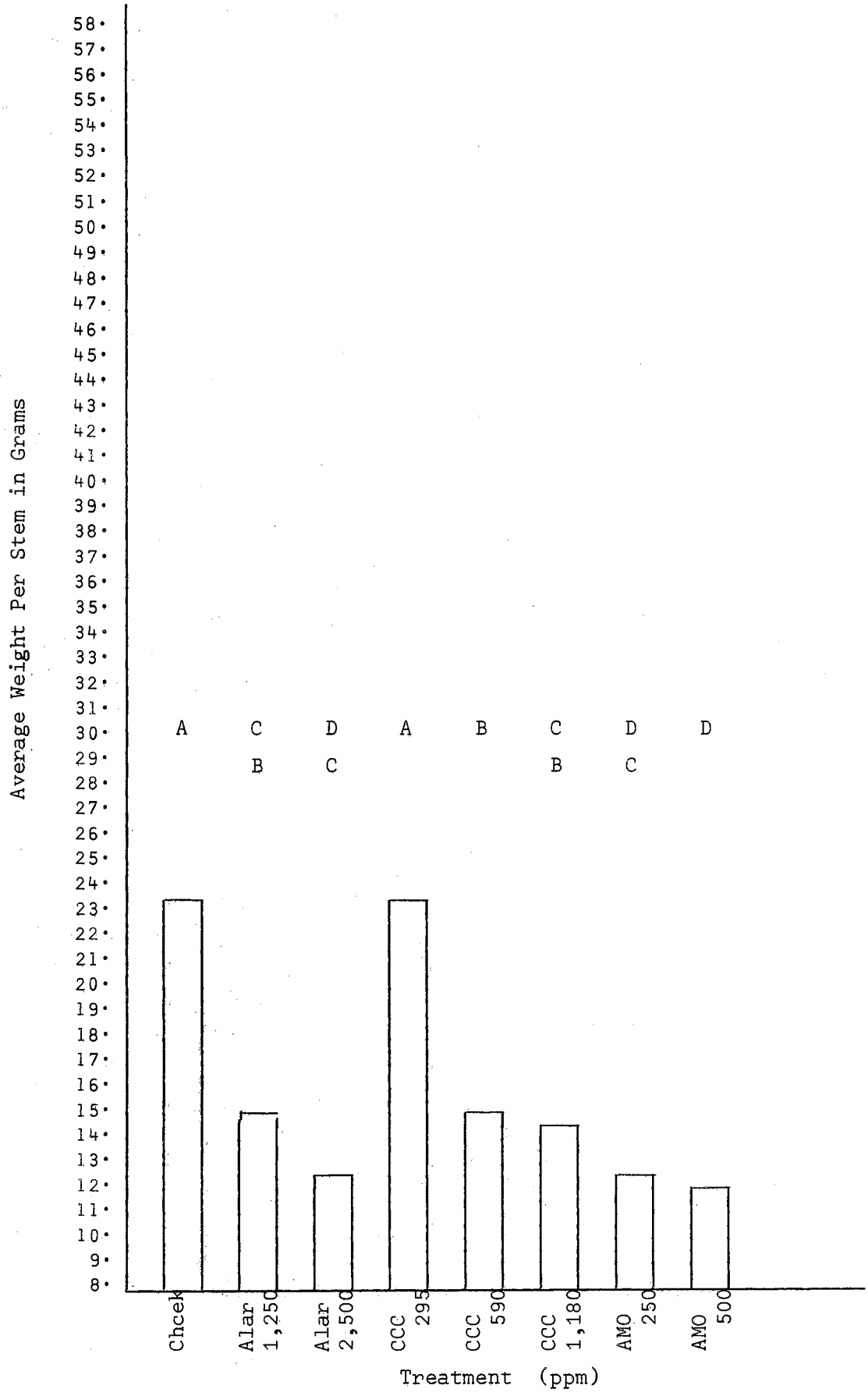

Weight of Leaves in Pounds
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
Check
Alar 1,250
Alar 2,500
CCC 295
CCC 590
CCC 1,180
AMO 250
AMO 500
Treatment (ppm)

Figure 20. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Stem Weight of Waldmann's Green Leaf Lettuce Plants (Trial III b, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 26 March 1968).


Average Weight Per Stem in Grams
58
57
56
55
54
53
52
51
50
49
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47
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45
44
43
42
41
40
39
38
37
36
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24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
A
C
B
D
C
A
B
C
B
D
C
D
Chcek
Alar 1,250
Alar 2,500
CCC 295
CCC 590
CCC 1,180
AMO 250
AMO 500
Treatment (ppm)

the only treatment in which stem weight was not reduced significantly.

Trial IV: The effects of spray applications of various concentrations of Alar, CCC and AMO on plant height of Burk's Selection are shown in Figure 21. All treatments caused a significant reduction in plant height. Figure 22 shows that the treatments significantly increased the number of leaves per plant as compared to the check. Although the treated plants had a greater number of leaves per pound than the check, the number of leaves per pound was less than that found in previous trials. This was due to the extremely large size of the individual leaves. Figure 23 shows the effects of Alar, CCC and AMO on the number of leaves per pound. It is shown in Figure 24 that there was no significant difference in total weight of the treatments as compared to the check. Figure 25 shows that weight of usable leaves is enhanced by reducing stem growth with growth retardants. Figure 26 shows that growth retardant treatments reduced stem weight significantly.

Trial V a: It was observed, Figure 27, that as the concentration of the growth retardants were increased, plant height of Grand Rapids cultivar was significantly reduced. It was shown in Figure 28 that the number of leaves per plant was increased significantly by various concentrations of Alar, CCC and AMO. The number of leaves per pound was also increased by spray applications of growth retardants as illustrated in Figure 29. Data in Figure 30 shows that there were significant differences in the wieght of plants. The leaf weights of the check and treated plants, Figure 31, were quite similar. This was attributed to the significant decreases in stem weight brought about by the chemical treatments as reported in Figure 32.

Trial V b: The cultivar Waldmann's Green was used in part 'b' of

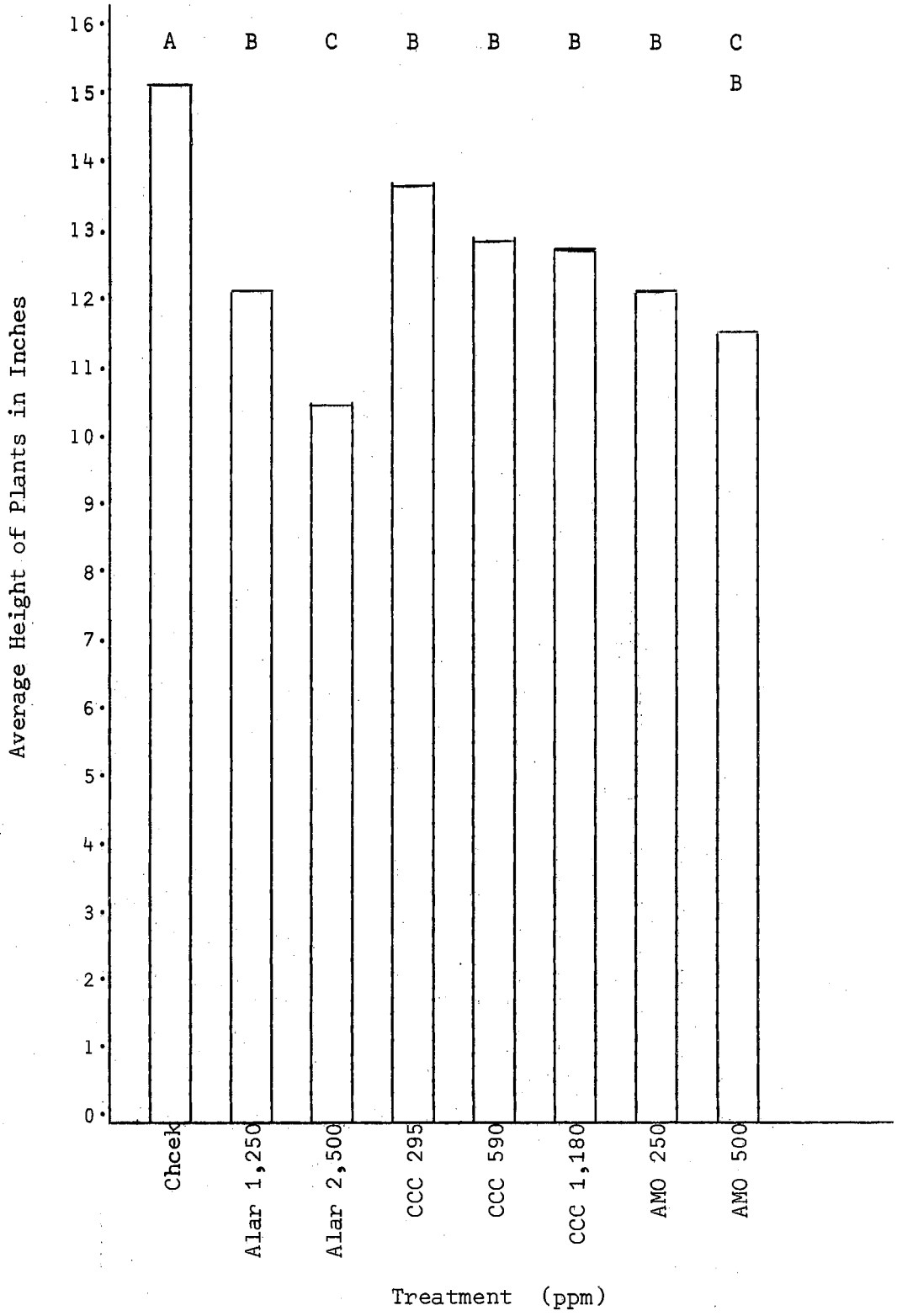


Figure 21. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Average Plant Height of Burk's Selection Leaf Lettuce Plants (Trail IV, Transplanted 6 Frebruary 1968, Treated 15 March 1968, Harvested 30 March 1968).

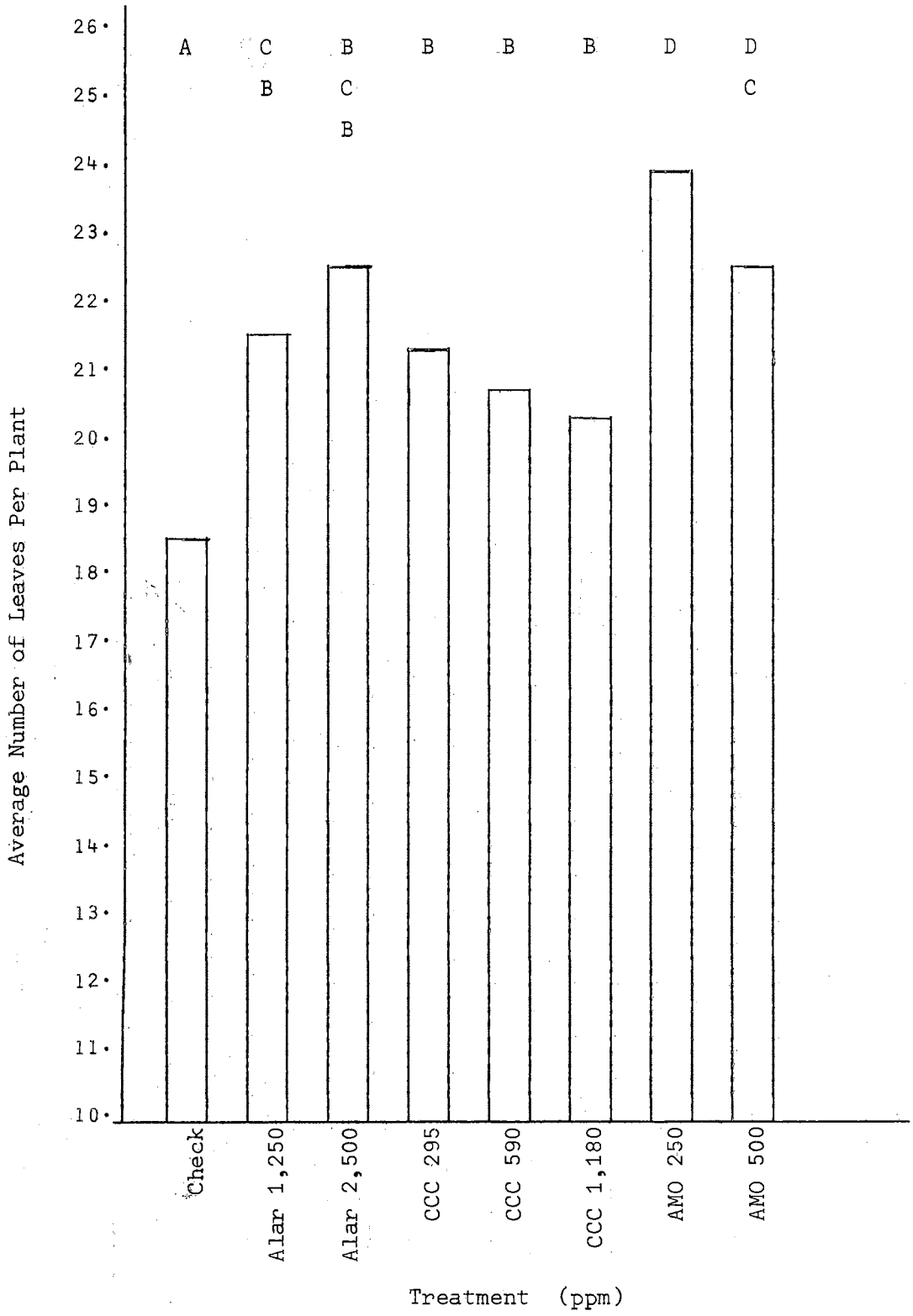
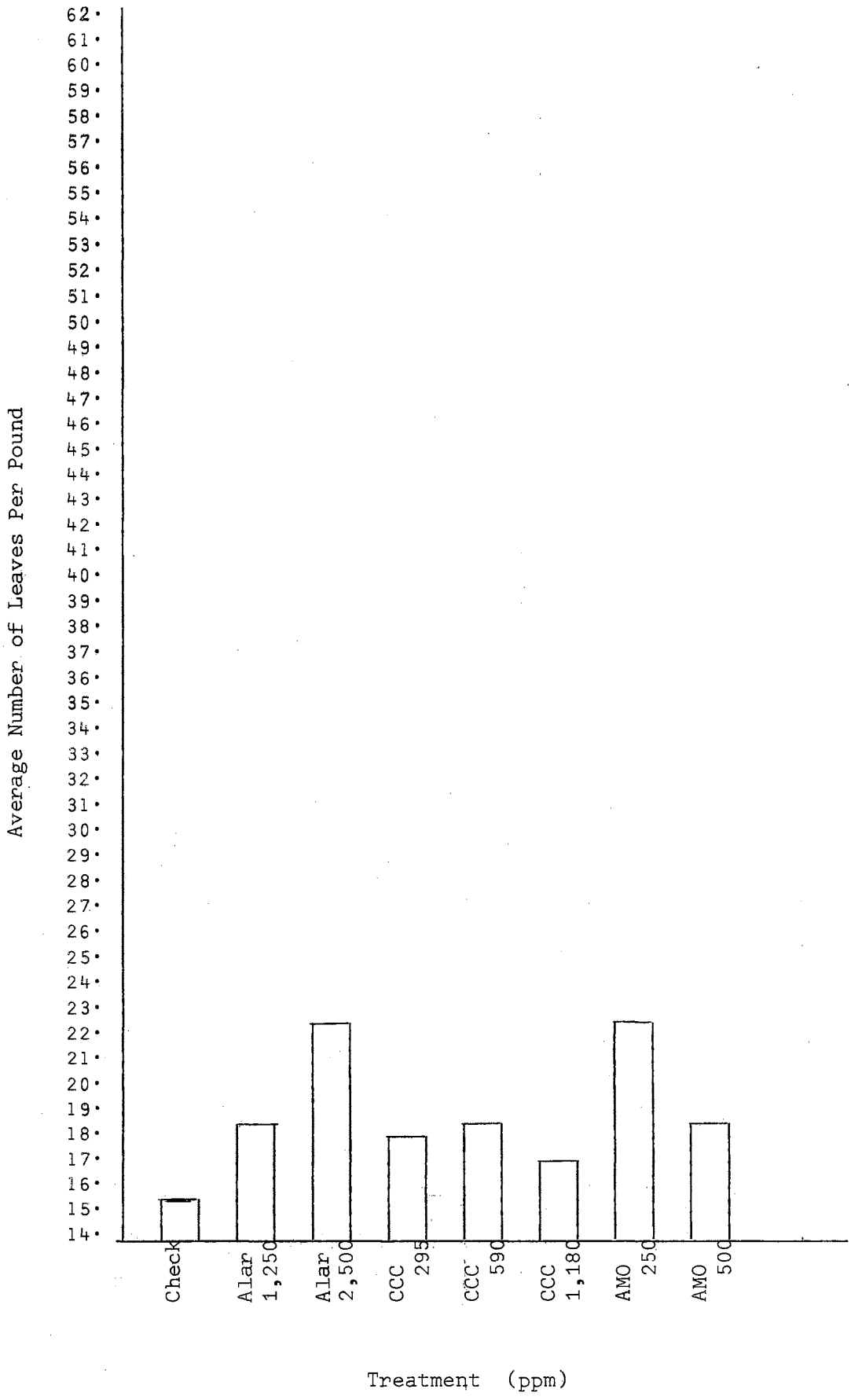


Figure 22. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Average Number of Leaves Per Plant of Burk's Selection Leaf Lettuce Plants (Trail IV. Transplanted 6 February 1968, Treated 15 March 1968, Harvested 30 March 1968).

Figure 23. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Number of Leaves Per Plant on Burk's Selection Leaf Lettuce Plants (Trial IV. Transplanted 6 February 1968, Treated 15 March 1968, Harvested 30 March 1968).


Average Number of Leaves Per Pound
62
61
60
59
58
57
56
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54
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51
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48
47
46
45
44
43
42
41
40
39
38
37
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34
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23
22
21
20
19
18
17
16
15
14
Check
Alar 1,250
Alar 2,500
CCC 295
CCC 590
CCC 1,180
AMO 250
AMO 500
Treatment (ppm)

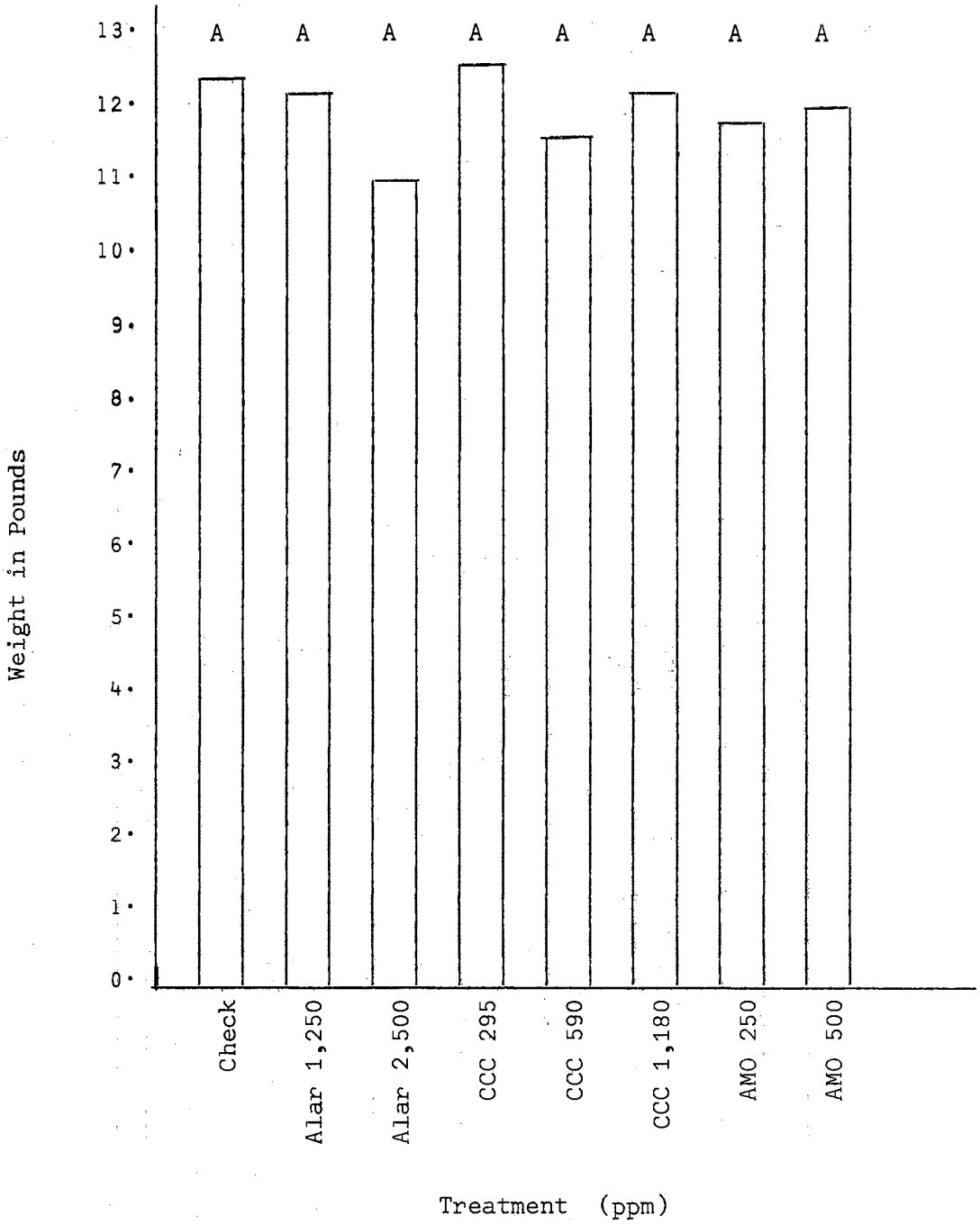


Figure 24. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Burk's Selection Leaf Lettuce Plants with Reference to Weight* (Trial IV. Transplanted 6 February 1968, Treated 15 March 1968, Harvested 30 March 1968).

*Weight of 10 plants.

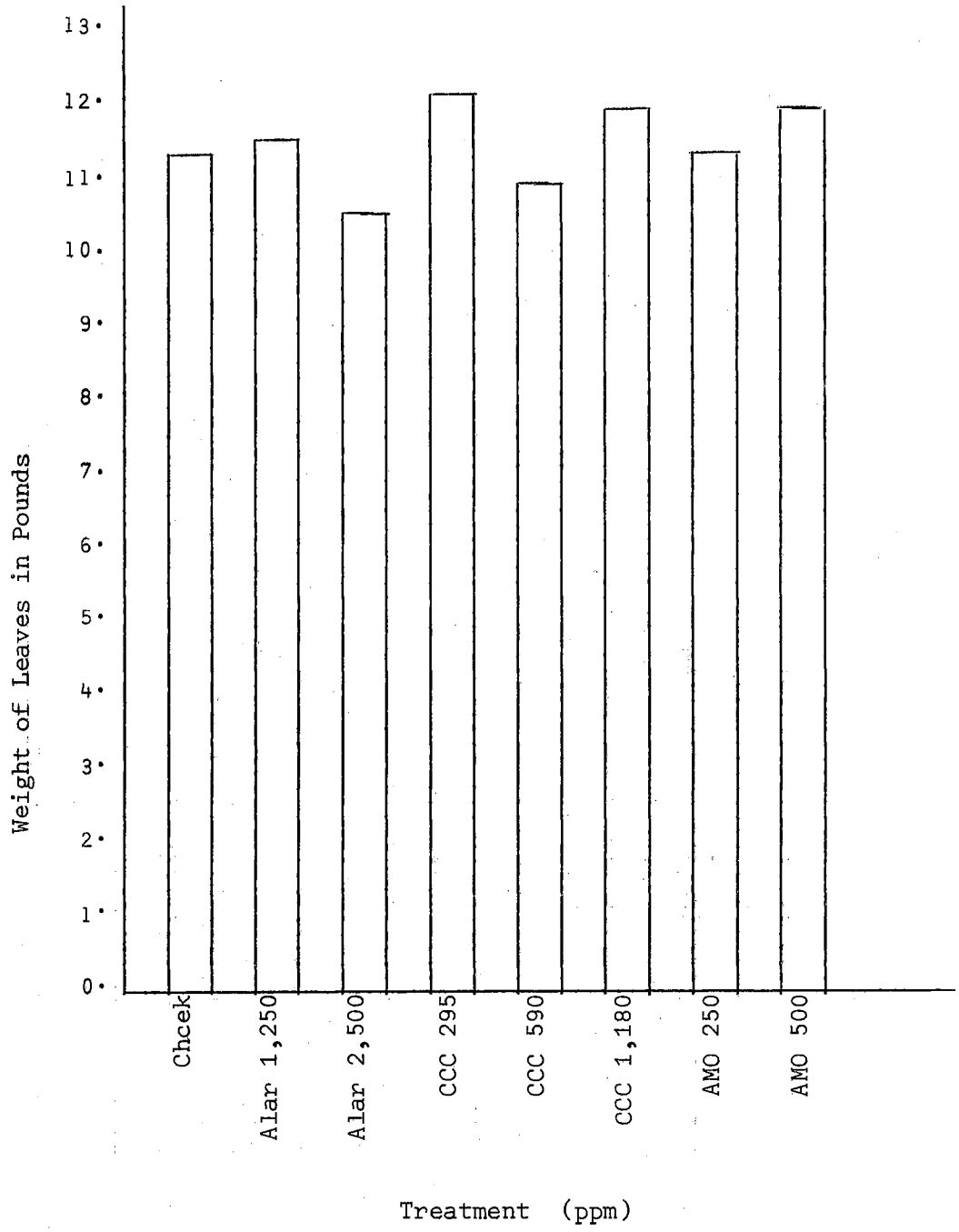
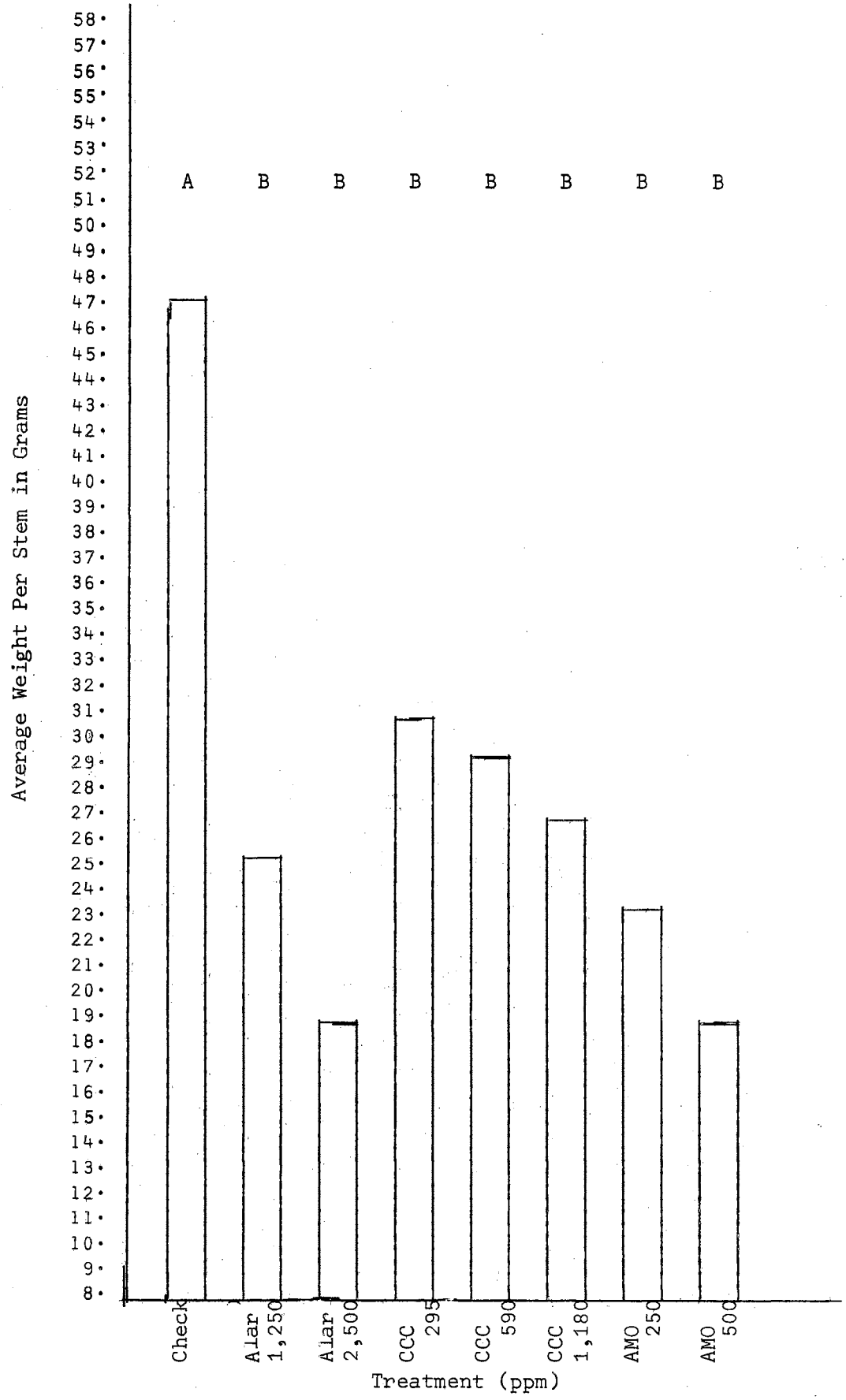


Figure 25. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Weight of Leaves* of Burk's Selection Leaf Lettuce Plants (Trial IV. Transplanted 6 February 1968, Treated 15 March 1968, Harvested 30 March 1968).

*Leaves of 10 plants.

Figure 26. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Weight per Stem of Burk's Selection Leaf Lettuce Plant (Trial IV. Transplanted 6 February 1968, Treated 15 March 1968, Harvested 30 March 1968).


Average Weight Per Stem in Grams
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
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21
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18
17
16
15
14
13
12
11
10
9
8
A
B
B
B
B
B
B
B
Check
Alar 1,250
Alar 2,500
CCC 295
CCC 590
CCC 1,180
AMO 250
AMO 500
Treatment (ppm)

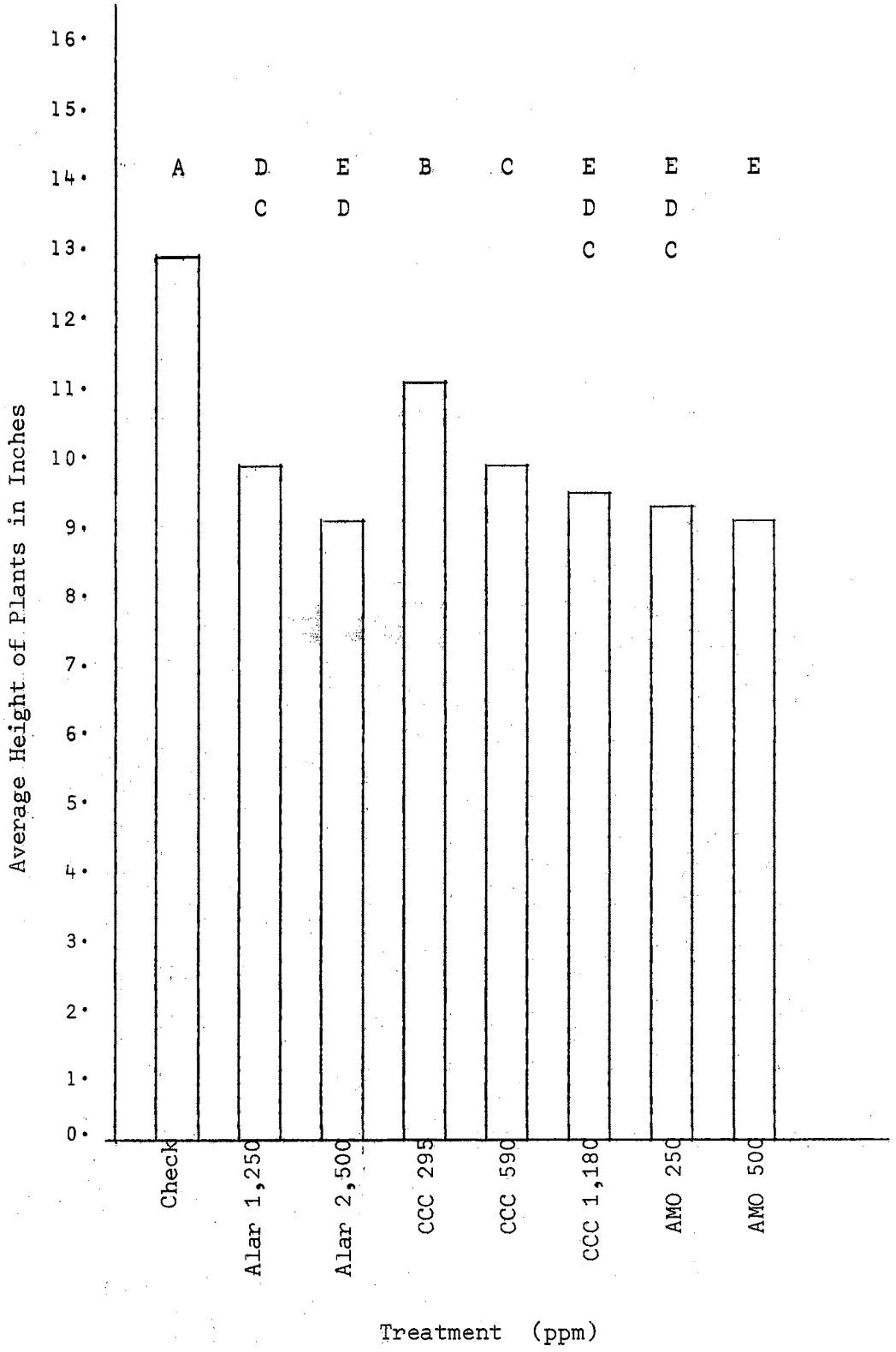


Figure 27. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Height of Grand Rapids Leaf Lettuce Plants (Trial V a. Transplanted 10 February 1968, Treated 2 March 1968, Harvested 11 April 1968).

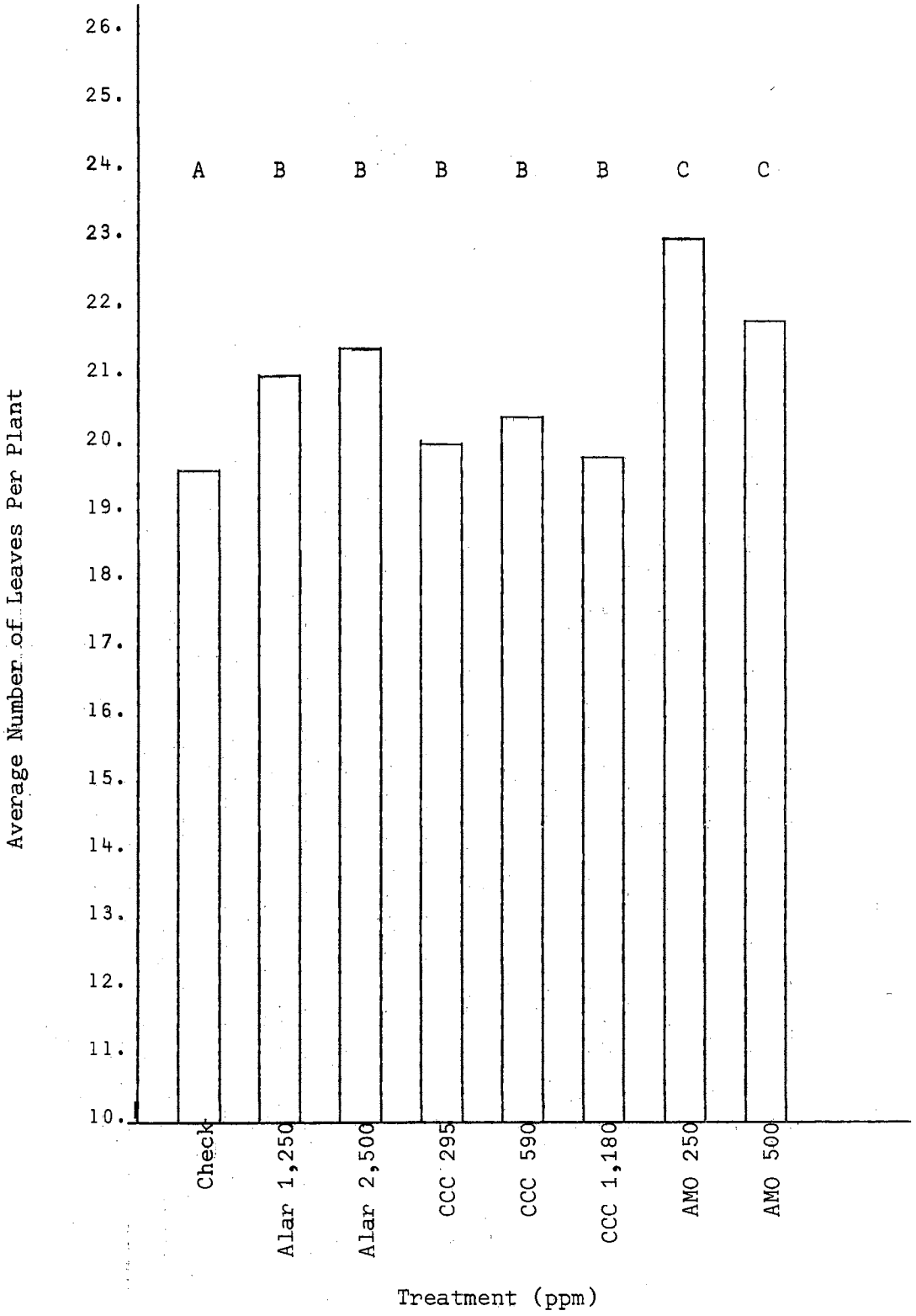
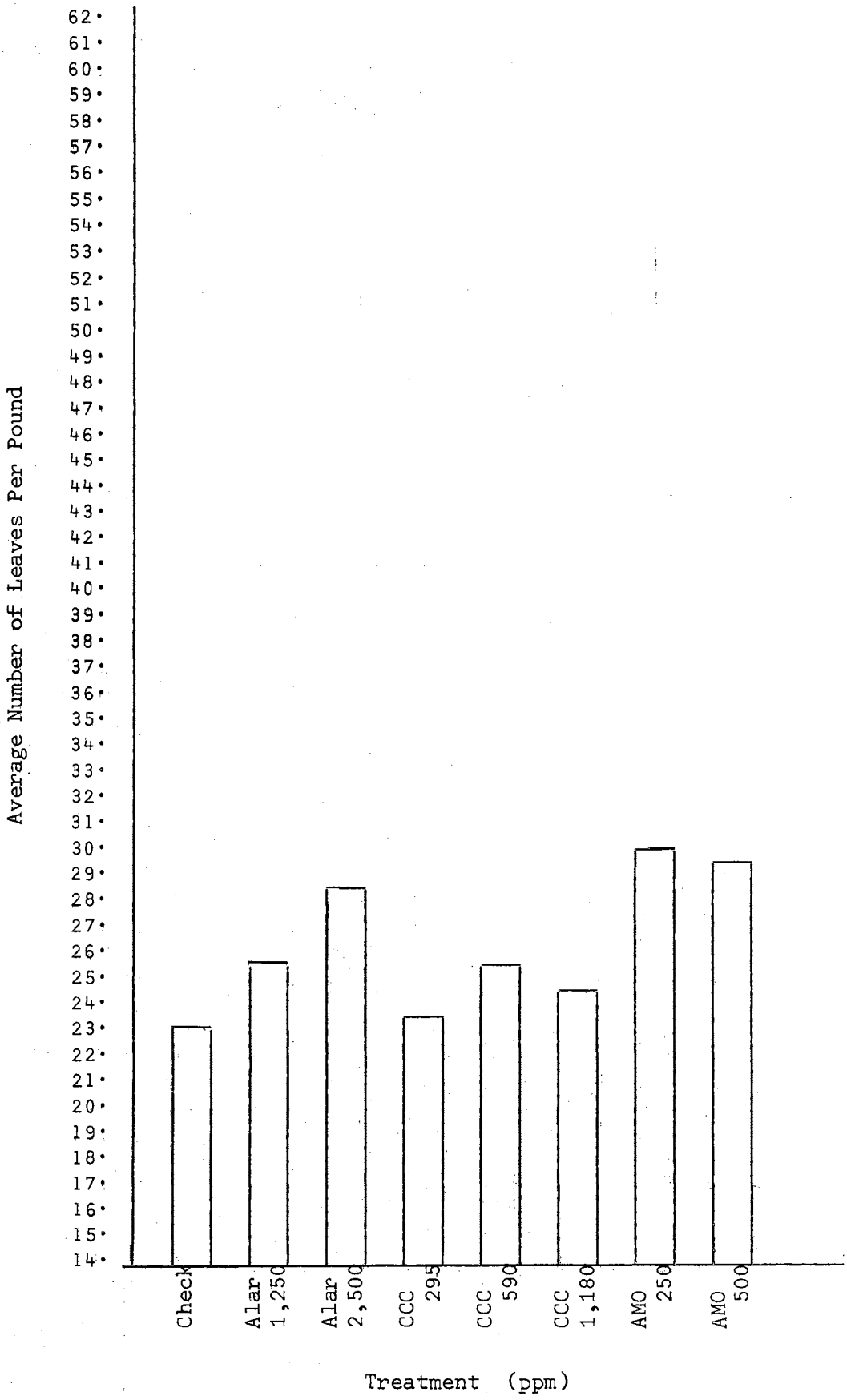


Figure 28. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Number of Leaves Per Plant of Grand Rapids Leaf Lettuce Plants (Trial V a, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 11 April 1968).

Figure 29. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Number of Leaves Per Pound of Grand Rapids Leaf Lettuce Plants (Trial V a, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 11 April 1968).


Average Number of Leaves Per Pound
62
61
60
59
58
57
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46
45
44
43
42
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21
20
19
18
17
16
15
14
Check
Alar 1,250
Alar 2,500
CCC 295
CCC 590
CCC 1,180
AMO 250
AMO 500
Treatment (ppm)

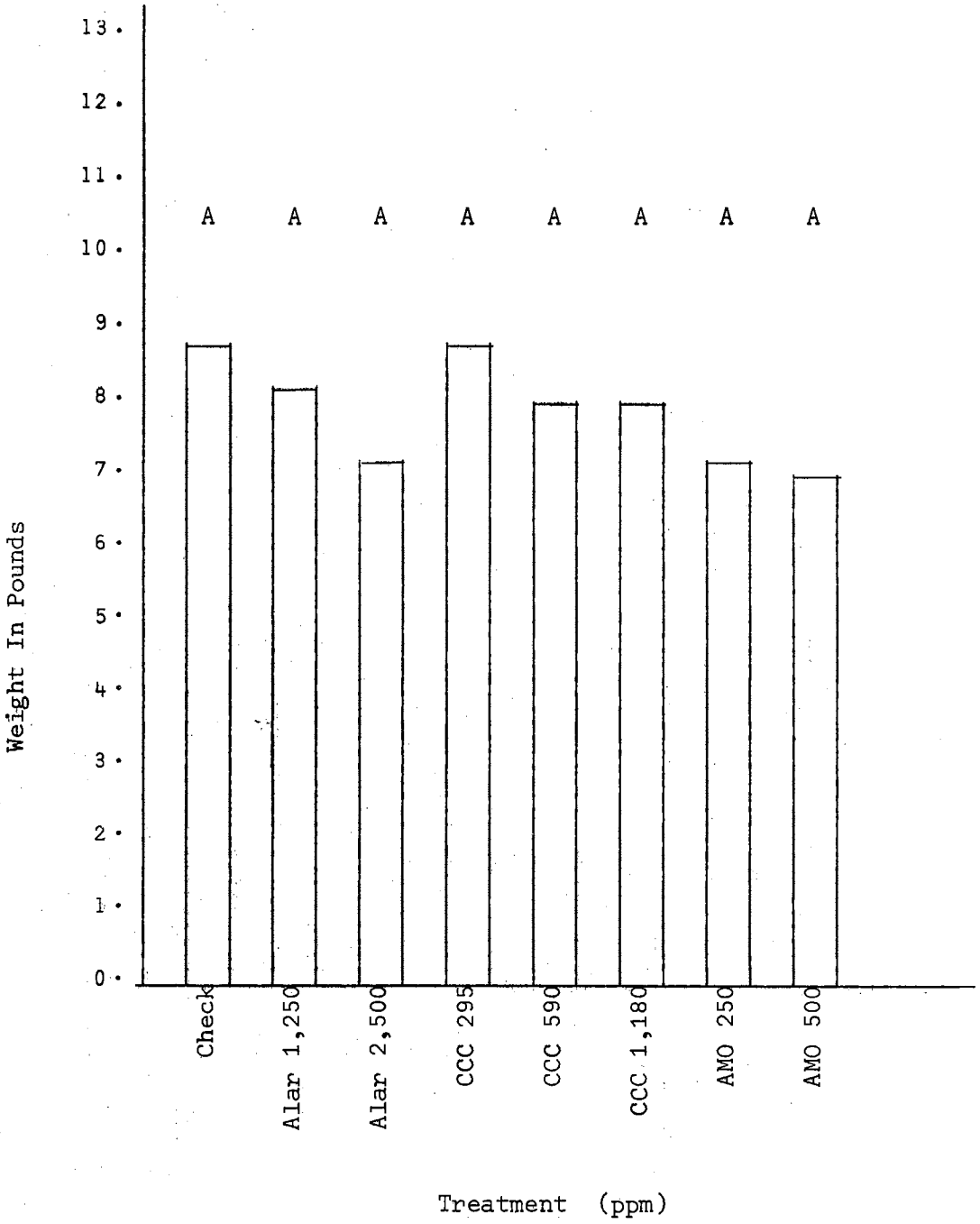


Figure 30. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Grand Rapids Leaf Lettuce Plants with Reference to Weight* (Trial V a, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 11 April 1968).

*Weight of 10 plants.

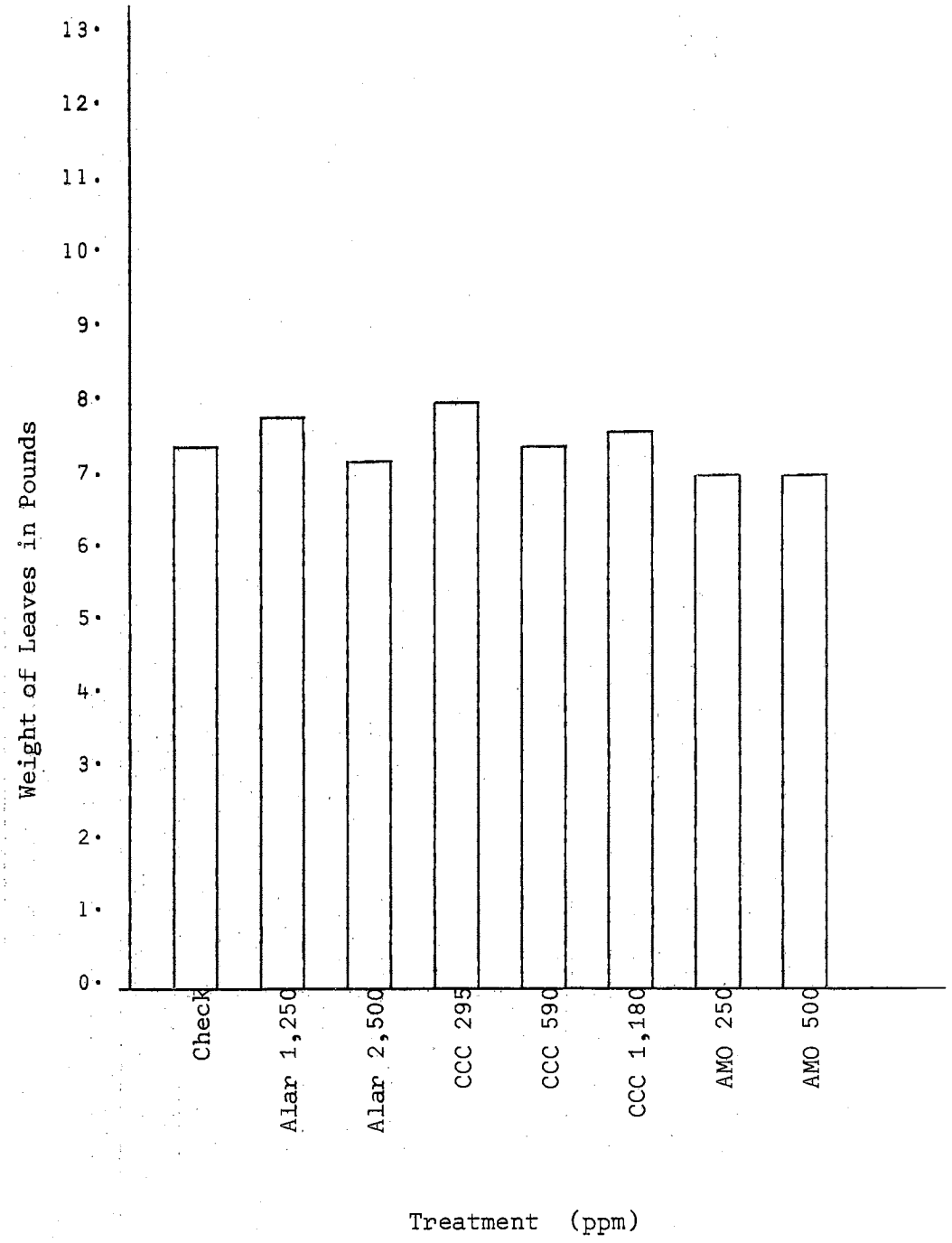
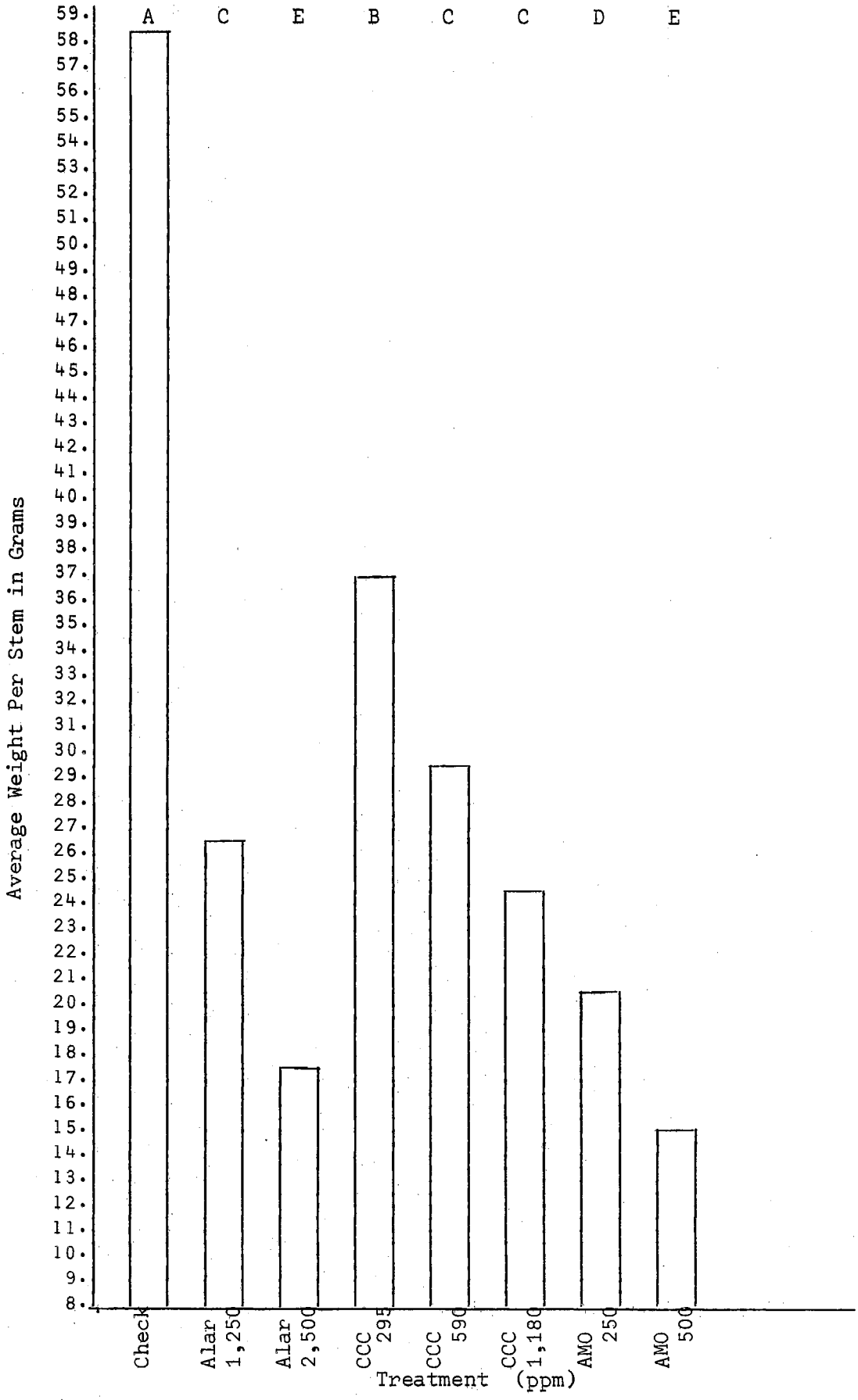


Figure 31. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Weight of Leaves* of Grand Rapids Leaf Lettuce Plants (Trial V a, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 11 April 1968).

*Leaves of 10 plants.

Figure 32. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Average Weight Per Stem of Grand Rapids Leaf Lettuce Plants. (Trial V a, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 11 April 1968).


A
C
E
B
C
C
D
E
Average Weight Per Stem in Grams
59.
58.
57.
56.
55.
54.
53.
52.
51.
50.
49.
48.
47.
46.
45.
44.
43.
42.
41.
40.
39.
38.
37.
36.
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18.
17.
16.
15.
14.
13.
12.
11.
10.
9.
8.
Check
Alar 1,250
Alar 2,500
CCC 295
CCC 590
CCC 1,180
AMO 250
AMO 500
Treatment (ppm)

trial V. The growth retardant treatments reduced significantly plant height as shown in Figure 33. The effect of growth retardants on the number of leaves per plant was not as marked as in previous trials. Only one treatment, AMO at 500 ppm, significantly increased the number of leaves per plant when compared to the check treatment, Figure 34. Two treatments, CCC at 295 ppm and 590 ppm, Figure 35, failed to increase the number of leaves per pound. Various concentrations of Alar, CCC and AMO as shown in Figure 36, caused no significant change in total weight. All of the chemical treatments, Figure 37, however, did increase leaf weight when compared to the check treatment. This was due to the significant reduction in stem weight brought about by the Alar, CCC and AMO treatments as reported in Figure 38.

In Table I, it is shown that bolting in leaf lettuce may be delayed for as long as 19 days when treated with Alar at 2,500 ppm. All of the chemical treatments, to a certain extent, delayed bolting. Table II shows the effect of various concentrations and times of applications of growth retardants on the delay of bolting in Grand Rapids leaf lettuce. The effects of spray applications of various concentrations and times of application on Waldmann's Green leaf lettuce on the delay of bolting are shown in Table III.

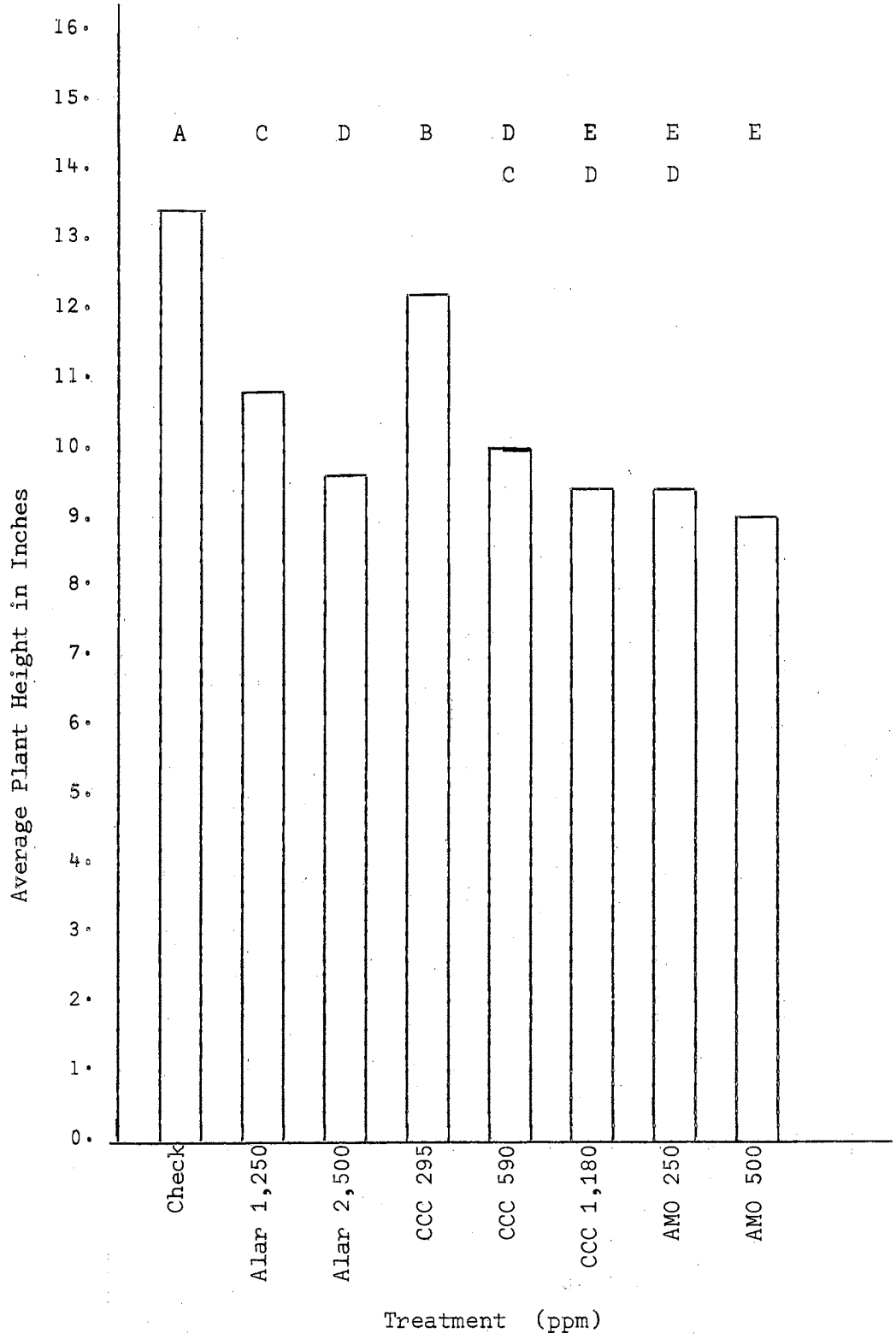


Figure 33. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Average Plant Height of Waldmann's Green Leaf Lettuce Plants (Trial V b, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 11 April 1968).

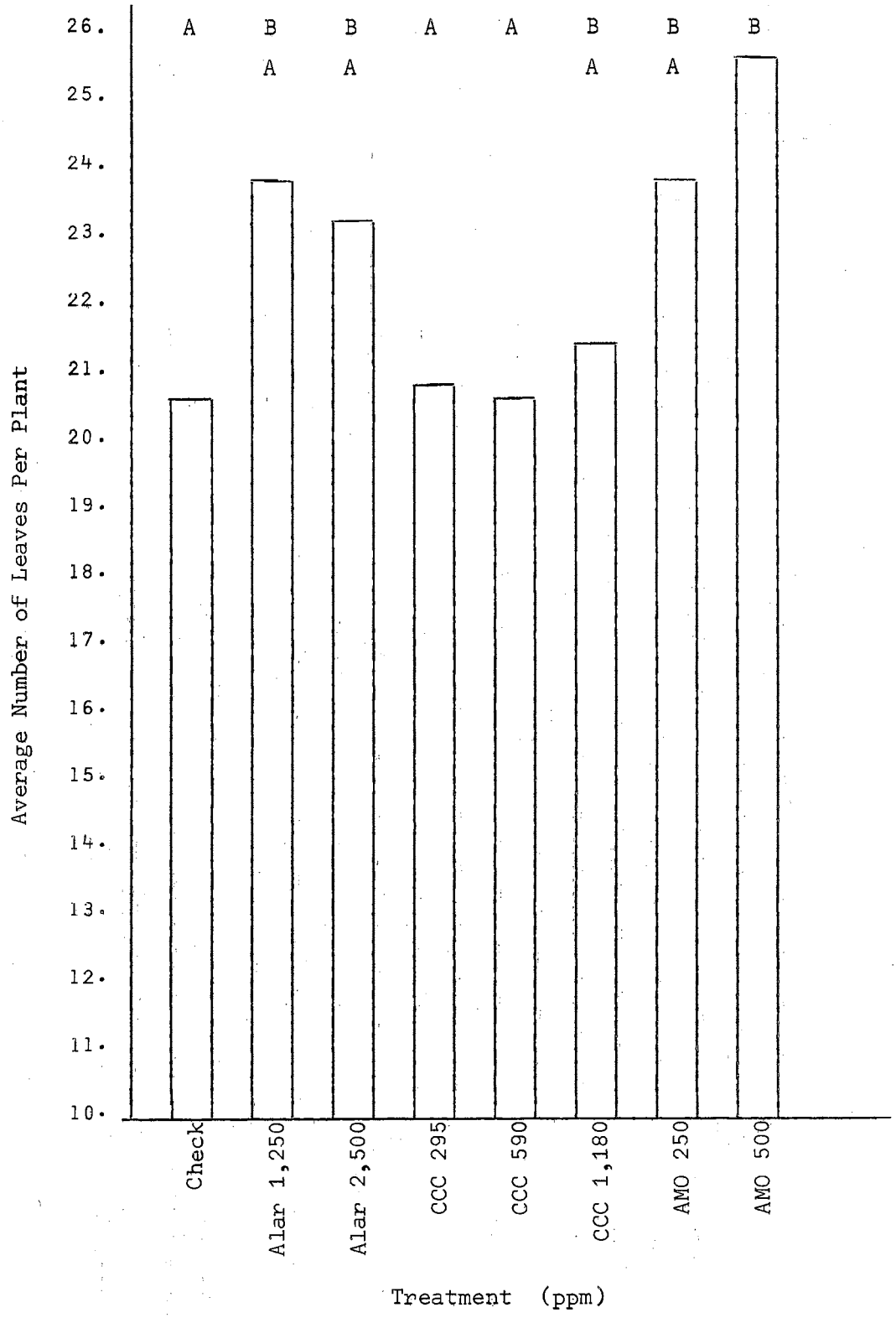
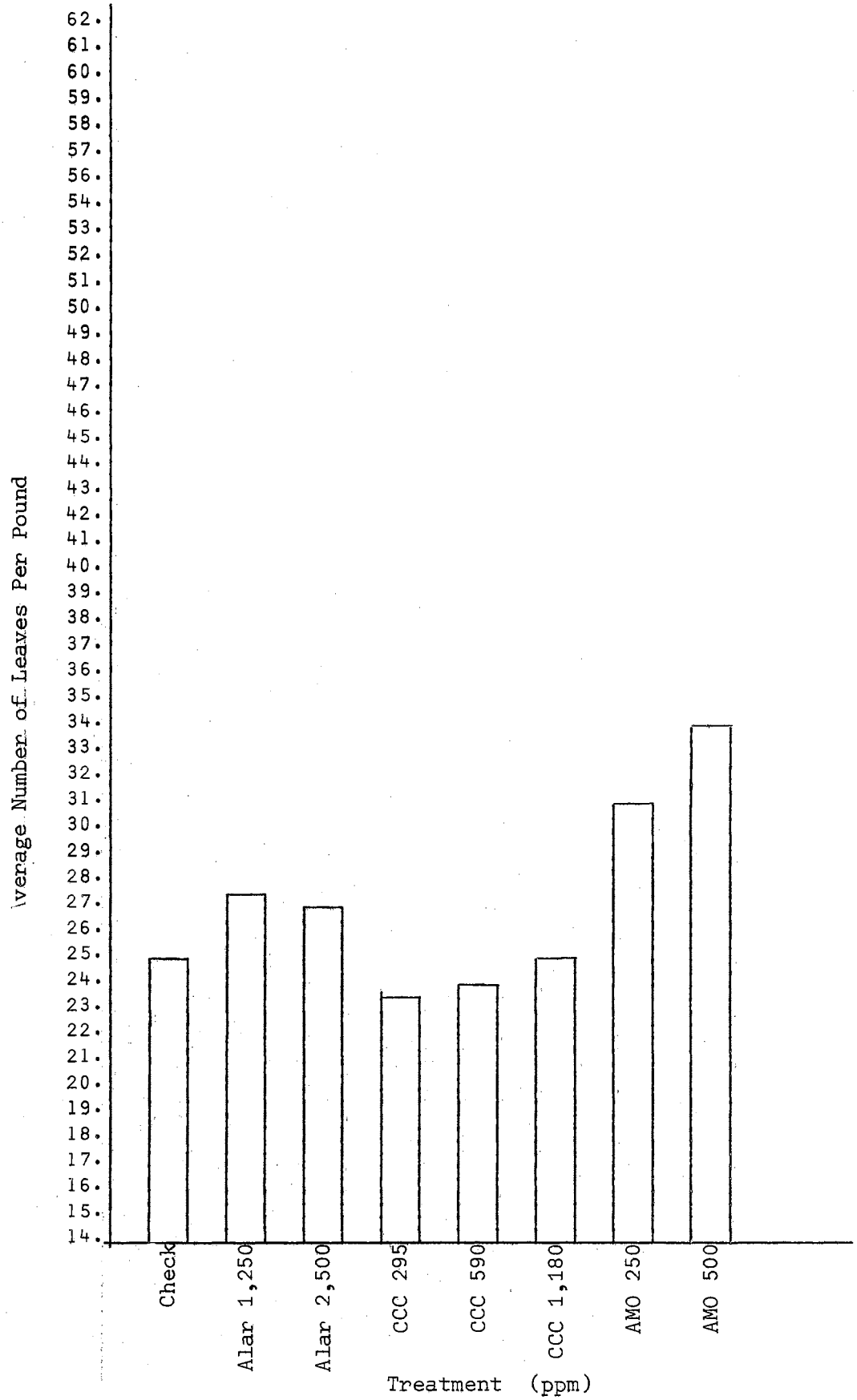


Figure 34. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Number of Leaves of Waldmann's Green Leaf Lettuce Plants (Trial V b, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 11 April 1968).

Figure 35. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Number of Leaves Per Pound of Waldmann's Green Leaf Lettuce Plants (Trial V b, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 11 April 1968).


Average Number of Leaves Per Pound
62.
61.
60.
59.
58.
57.
56.
54.
53.
52.
51.
50.
49.
48.
47.
46.
45.
44.
43.
42.
41.
40.
39.
38.
37.
36.
35.
34.
33.
32.
31.
30.
29.
28.
27.
26.
25.
24.
23.
22.
21.
20.
19.
18.
17.
16.
15.
14.
Check
Alar 1,250
Alar 2,500
CCC 295
CCC 590
CCC 1,180
AMO 250
AMO 500
Treatment (ppm)

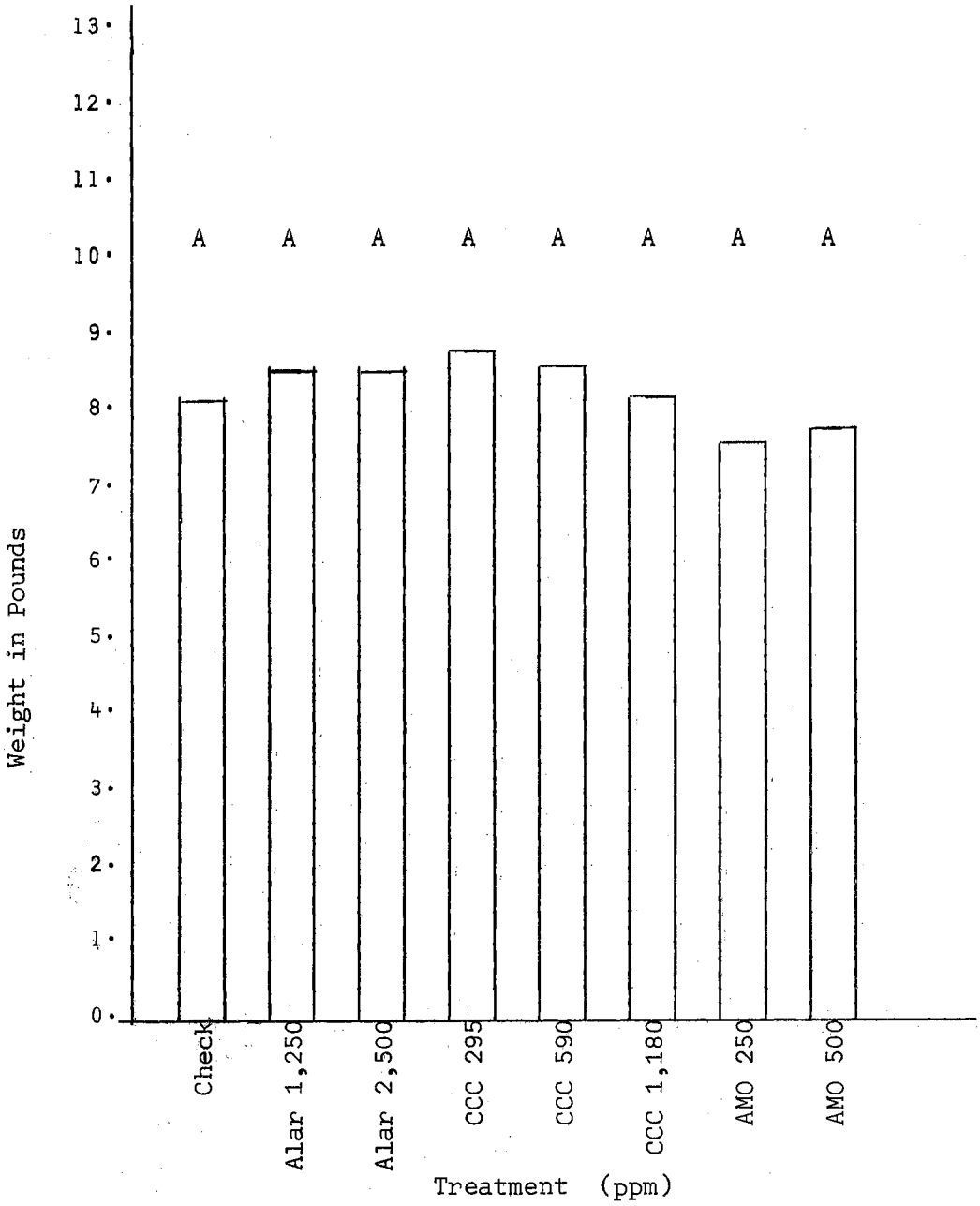


Figure 36. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Waldmann's Green Leaf Lettuce Plants with Reference to Weight* (Trial V b, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 11 April 1968).

*Weight of 10 plants.

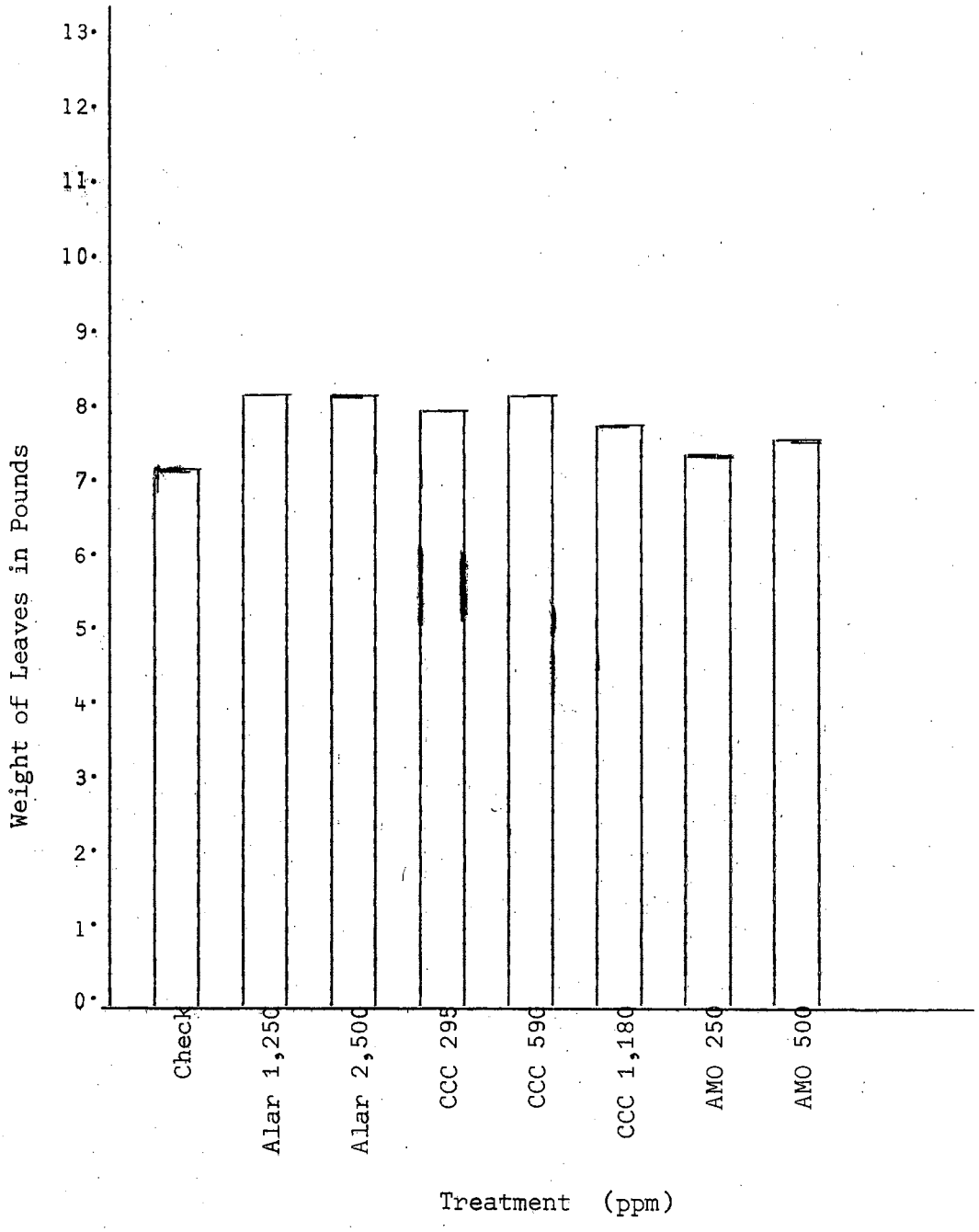
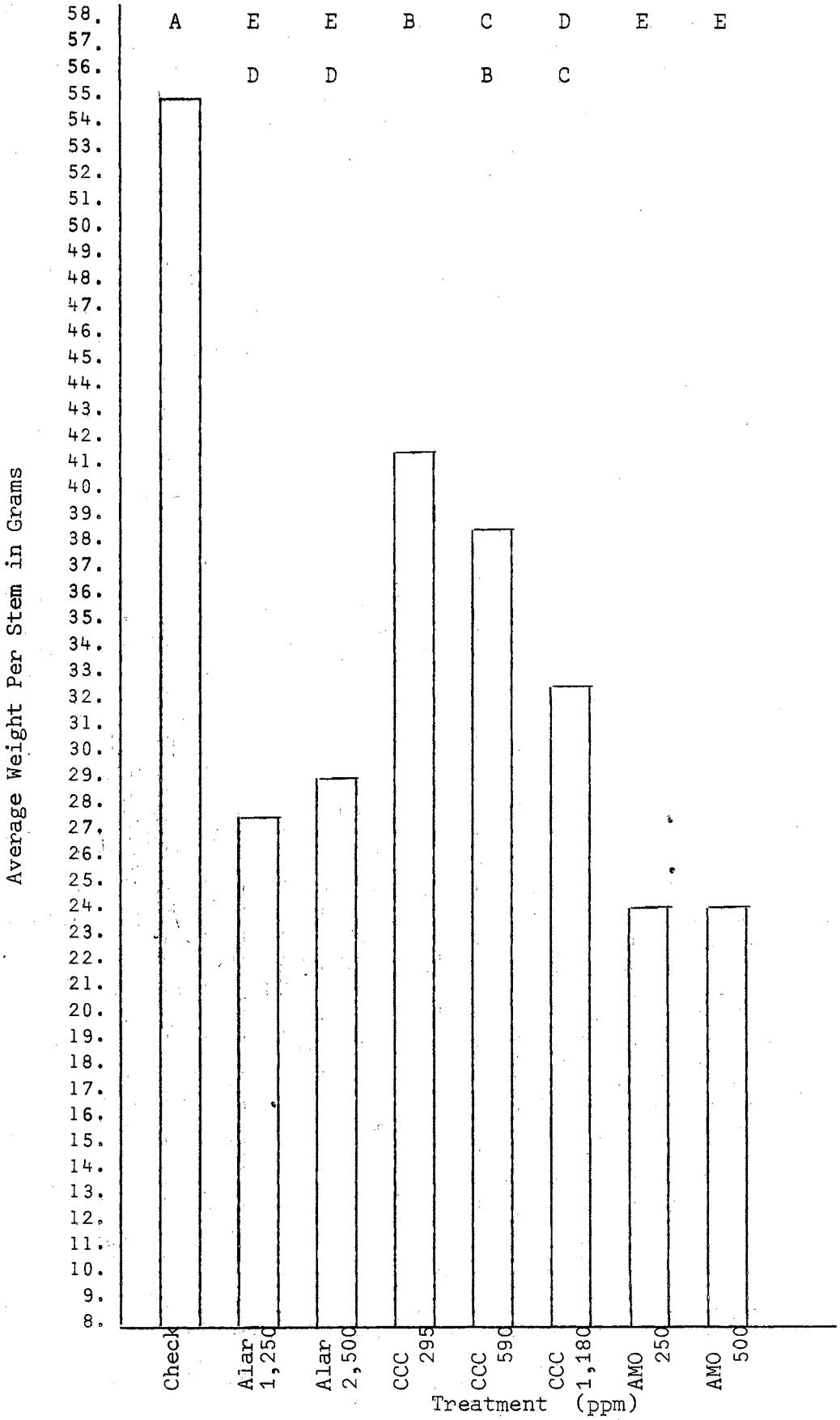


Figure 37. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on Weight of Leaves* of Waldmann's Green Leaf Lettuce Plants (Trial V b, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 11 April 1968).

*Leaves of 10 plants.

Figure 38. Effect of Spray Applications of Various Concentrations of Alar, CCC and AMO on the Average Stem Weight of Waldmann's Green Leaf Lettuce Plants (Trial V b, Transplanted 10 February 1968, Treated 2 March 1968, Harvested 11 April 1968).


A E E B C D E E
D D B C
58.
57.
56.
55.
54.
53.
52.
51.
50.
49.
48.
47.
46.
45.
44.
43.
42.
41.
40.
39.
38.
37.
36.
35.
34.
33.
32.
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23.
22.
21.
20.
19.
18.
17.
16.
15.
14.
13.
12.
11.
10.
9.
8.
Average Weight Per Stem in Grams
Check
Alar 1,250
Alar 2,500
CCC 295
CCC 590
CCC 1,180
AMO 250
AMO 500
Treatment (ppm)

TABLE I

THE EFFECT OF SPRAY APPLICATIONS OF VARIOUS CONCENTRATIONS OF ALAR, CCC AND AMO ON DELAYING BOLTING IN BURK'S SELECTION LEAF LETTUCE

Treatment	Number of days bolting delayed
Alar at 1,250 ppm (8 leaf stage)	15 days
Alar at 2,500 ppm (8 leaf stage)	19 days
CCC at 295 ppm (8 leaf stage)	2 days
CCC at 590 ppm (8 leaf stage)	5 days
CCC at 1,180 ppm (8 leaf stage)	9 days
AMO at 250 ppm (8 leaf stage)	8 days
AMO at 500 ppm (8 leaf stage)	11 days

TABLE II

THE EFFECT OF SPRAY APPLICATIONS OF VARIOUS CONCENTRATIONS OF ALAR, CCC AND AMO ON DELAYING BOLTING IN GRAND RAPIDS LEAF LETTUCE

Treatment	Number of days bolting delayed
Alar at 1,250 ppm (8 leaf stage)	13 days
Alar at 2,500 ppm (8 leaf stage)	17 days
CCC at 295 ppm (8 leaf stage)	0 days
CCC at 590 ppm (8 leaf stage)	2 days
CCC at 1,180 ppm (8 leaf stage)	5 days
AMO at 250 ppm (8 leaf stage)	10 days
AMO at 500 ppm (8 leaf stage)	11 days
Alar at 1,250 ppm (2 leaf stage)	9 days
CCC at 295 ppm (2 leaf stage)	6 days
AMO at 250 ppm (2 leaf stage)	3 days

TABLE III

THE EFFECT OF SPRAY APPLICATIONS OF VARIOUS CONCENTRATIONS OF ALAR, CCC AND AMO ON DELAYING BOLTING IN WALDMANN'S GREEN LEAF LETTUCE

Treatment	Number of days bolting delayed
Alar at 1,250 ppm (8 leaf stage)	16 days
Alar at 2,500 ppm (8 leaf stage)	18 days
CCC at 295 ppm (8 leaf stage)	3 days
CCC at 590 ppm (8 leaf stage)	4 days
CCC at 1,180 ppm (8 leaf stage)	7 days
AMO at 250 ppm (8 leaf stage)	10 days
AMO at 500 ppm (8 leaf stage)	13 days
Alar at 1,250 ppm (2 leaf stage)	7 days
CCC at 295 ppm (2 leaf stage)	3 days
AMO at 250 ppm (2 leaf stage)	5 days

CHAPTER V

DISCUSSION AND CONCLUSIONS

At this time leaf lettuce production in Oklahoma can best be done during the cool months of the year due to the initiation and rapid development of seed stalks during the summer months (May through September). The treatment of leaf lettuce with spray applications of various concentrations of Alar, CCC and AMO-1618 apparently activates some chemical change or changes within the plants which delayed seed stalk initiation even when the temperatures were high (70° to 80°F).

In the study reported herein, the initiation of seed stalks in Grand Rapids, Waldmann's Green and Burk's Selection leaf lettuce cultivars was satisfactorily suppressed not only during the winter months, but also during the early summer period by the use of growth retardant spray treatments. In trial V which ended in April, during which time the daily temperature rose to 80°F, the seed stalks seemed to be initiated more readily. Apparently when the temperature becomes too high the growth retardants are not as effective in inhibiting bolting. On the basis of these results, it is believed that growth retardants can be successfully substituted for cool temperatures in leaf lettuce production. Further research must be done however, to determine more precisely what concentrations of growth retardants to use and the stage of plant growth at the time of application needed for the best response. Growth retardants should also be tried on other plants that respond to

temperature in a manner similar to leaf lettuce.

It should be noted that, in general, the number of leaves per plant and the number of leaves per pound were increased by the chemical treatments in all five trials. The increase in the number of leaves per plant was not expected, but creates a good selling point for the use of retardants on leaf lettuce. The increase in the number of leaves per pound was due to the significant decreases in stem length and weight of the treated plants. These results support Cathey's (3) suggestion that weight reduction was due primarily to the reduction of stem length in treated plants. Therefore, when the stem weight was reduced the amount of usable leaves was increased markedly. It should be noted that although total plant weight was generally reduced by growth retardant treatments in all trials, the reduction was not significant in any trial. This was due to the significant increase in the number of leaves per plant.

The treated plants were judged to be of better quality than the check plants by qualified dietitions. Their decision was based upon the size, shape and color of the leaves. The leaves were more uniform in size. There were no extremely large or small leaves. The shape of the leaves was more compact due to the reduction in petiole length. This helped reduce the waste when the lettuce plants were used. The green color of the leaves was enhanced much as Wirwille and Mitchell (22) and Cathey (3) had suggested in earlier work. Thus, it can be concluded, that all of the growth retardant treatments produced plants that were more saleable than the check plants in all trials.

Of the two plant growth stages at which the treatments were applied, bolting was delayed longer at the 8 leaf stage than at the 2

leaf stage as shown in Tables I, II, and III. This was the only apparent advantage found for either particular age of the plants when the chemicals were applied.

CHAPTER VI

SUMMARY

The studies reported herein relate to the effect of spray spplications of various concentrations of Alar, CCC and AMO-1618 on certain phases of the growth and development of leaf lettuce.

Five trials of greenhouse grown leaf lettuce were sprayed with various concentrations of growth retardants at the two and eight leaf stages. Plant height was significantly reduced on the plants receiving growth retardant treatments. The treated plants had a significant increase in the number of leaves per plant in all trials, while the total weights of the treated plants were not reduced significantly. The chemical treatments at both growth stages delayed bolting; however, the treatments applied at the eight leaf stage delayed bolting longer than did the treatments applied at the two leaf stage. All growth retardant treatments produced saleable quality plants, although the Alar treatments produced the more desirable plants.

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APPENDIX A

APPENDIX A

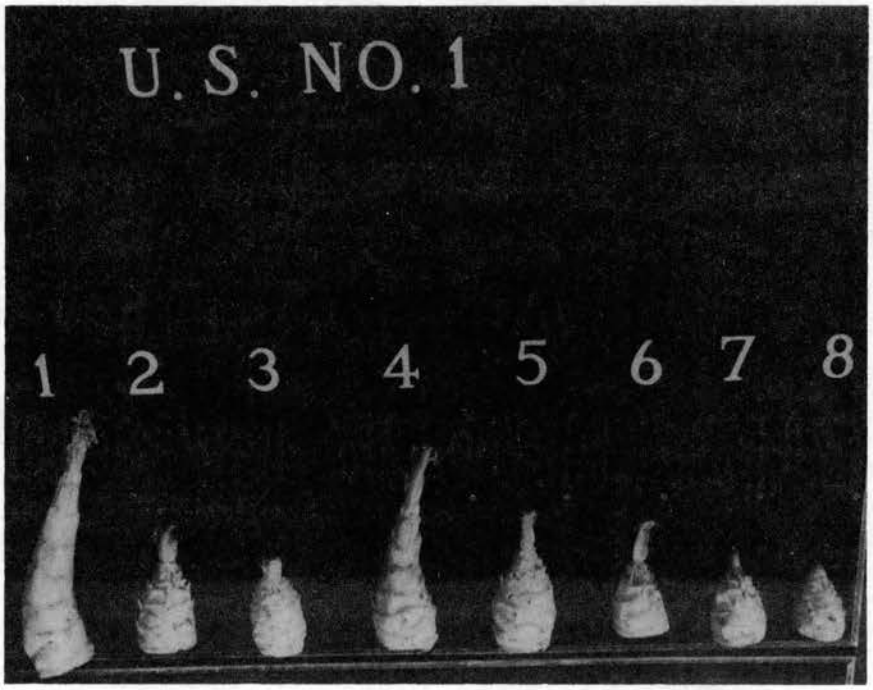
THE EFFECT OF ALAR ON PLANT HEIGHT

Plant on left is a Check plant Plant on right is a plant which was treated with Alar at 2,500 ppm.

APPENDIX B

APPENDIX B

THE EFFECT OF VARIOUS CONCENTRATIONS OF ALAR, CCC AND AMO ON STEM SIZE OF GRAND RAPIDS

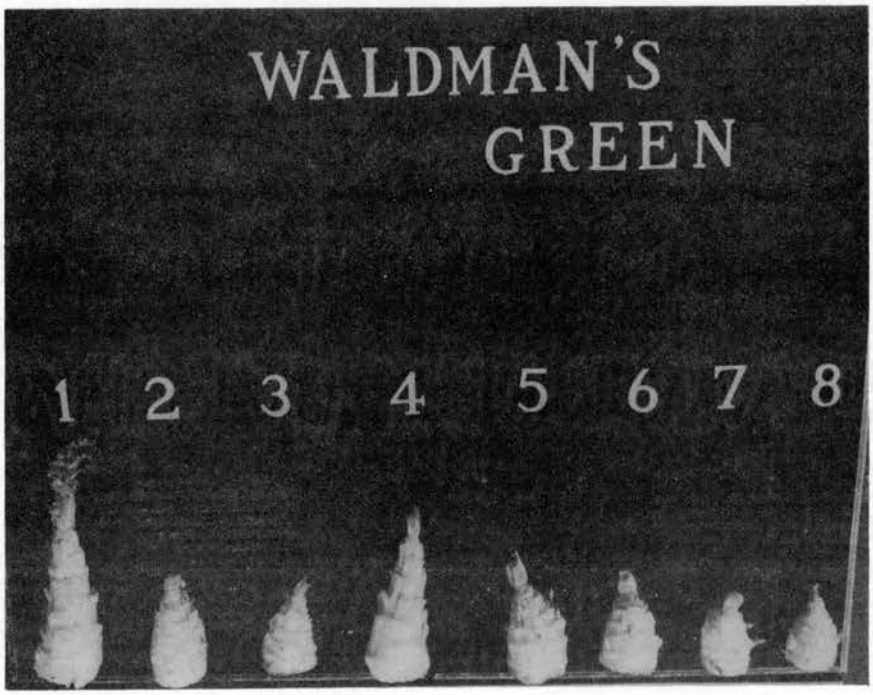


The treatments are: 1-check; 2-Alar at 1,250 ppm; 3-Alar at 2,500 ppm; 4-CCC at 295 ppm; 5-CCC at 590 ppm; 6-CCC at 1,180 ppm; 7-AMO at 250 ppm and 8-AMO at 500 ppm.

APPENDIX C

APPENDIX C

THE EFFECT OF VARIOUS CONCENTRATIONS OF ALAR, CCC AND AMO ON STEM SIZE OF WALDMANN"S GREEN



The treatments are: 1-check; 2-Alar at 1,250 ppm; 3-Alar at 2,500 ppm; 4-CCC at 295 ppm; 5-CCC at 590 ppm; 6-CCC at 1,180 ppm; 7-AMO at 250 ppm and 8-AMO at 500 ppm.

VITA

Willis Otis Johnson

Candidate for the Degree of

Master of Science

Thesis: THE EFFECT OF CERTAIN GROWTH RETARDANTS ON PLANT GROWTH AND SEED STALK RETARDATION OF LEAF LETTUCE.

Major Field: Horticulture

Biographical:

Personal Data: Born in Shattuck, Oklahoma, October 24, 1944, the son of I. E. and Beulah Johnson.

Education: Graduated from Arnett High School, Arnett, Oklahoma in 1962; received Bachelor of Science degree from Oklahoma State University in Agriculture Education, January 1967; completed requirements for the Master of Science degree, May, 1969.

Professional Experience: Second Lieutenant U.S. Army Reserve; graduate teaching assistant, Oklahoma State University, 1967-1968.