STUDIES ON THE EFFECT OF GROWTH REGULATORS IN AMARANTHUS (*Amaranthus gangeticus*, L.)

By

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A

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This is to certify that the thesis herewith submitted contains the results of bona-fide research work carried out by Sri K. Philip Zachariah under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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I N T R O D U C T I O N

INTRODUCTION

Among vegetables, Amaranthus (Amaranthus gangeticus L.) is a favourite plant of many. It is classified as a leafy vegetable and all parts of the plant are used for culinary purposes. Although cheaper in price, this vegetable is richer in nutritive value than many other plants. Besides being a rich source of vitamins A, B and C, it contains 4.9% proteins, 5.7% carbohydrates and 21.4 mg./100 gm. of iron (Wealth of India, as quoted from Health Bulletin No.23, 1941, 29). It is probably the richest source of iron for human consumption. Any enhancement in the yield of this vegetable crop of high nutritive value will be of great importance to agriculture.

Manurial trials, though effective in increasing the yield of plants have their limitations. Since the accidental discovery of growth regulating substances and the evolution of knowledge stemmed therefrom many interested workers in the field of agriculture have explored the possibilities of exploiting this new knowledge for the betterment of crop production. The achievements gained so far are encouraging.

The knowledge so far accumulated presents spectacular as well as unsuccessful results. The various experiments so far conducted were aimed at promoting seed germination and breaking of seed dormancy, to improve and hasten root initiation, to delay leaf abscission, to promote general growth, to increase flowering and fruit-set and to attain various other specific requirements of scientific agriculture.

In western countries the use of hormones is revolutionising agriculture. A more scientific approach, that is being made of late, involving the effect of growth regulators in altering the biochemical changes and metabolic pathways, presents possibilities of far reaching importance. Effects of auxins and gibberellins in increasing or decreasing various carbohydrate fractions, proteins, fats and vitamins have been reported. Although no concrete conclusions can be drawn from the existing knowledge about the effects mentioned above, the need to carry out further work on the various aspects of hormone physiology, fundamental as well as applied, becomes imperative.

In the present investigation an effort is made to evaluate the effects of indole acetic acid, indole butyric acid and gibberellic acid on the morphological growth of Amaranthus gangeticus L. Although any kind of

biochemical estimation does not form part of the present work the results obtained by Yabuta et al., (1941) that gibberellic acid increased the ascorbic acid content of etiolated Soyabeans, appeared to be a tempting and important information.

Improvement of amaranthus crop can be brought about by two different methods. Any investigation aimed at increasing the total yield or the nutrient value or both ought to be useful for vegetable culture. Although inconclusive, instances are many of the ability of hormones to enhance both these qualities. The possibility of increasing the production of leafy vegetables was strengthened by the results obtained by Jauhari et al., (1960) on leafy vegetable like spinach. In the present investigation, an effort is being undertaken to increase the yield of such vegetable crop of comparatively high nutritive value.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Study of hormones arose accidentally from the enquiries of Darwin (1880) on the mechanism of phototropism. During the last thirty years which have elapsed since the discovery of hormones as natural growth promoters in higher plants, extensive research efforts have been made on the various aspects, fundamental and applied, of hormone physiology. Excellent reviews on the subject have appeared from time to time. Larsen (1951) has reviewed the various investigations on the formation, occurrence and inactivation of growth substances. Bonner and Bandursky (1952) reviewed the studies on the physiology, pharmacology and biochemistry of the auxins. Audus (1953) in his monograph on growth regulators has exhaustively dealt with its various aspects. Gordon (1954) has also reviewed the publications on the occurrence, formation and inactivation of auxins. Muir and Hansch (1955) and Steward and Shantz (1955) have reviewed the chemical aspect of hormone action.

Even after such extensive studies workers of the present day are still exploring the ways of using these growth regulators to meet the various requirements of modern agriculture. The present review mostly confines to the works on the effects of various growth regulators on the general growth and yield of plants, with special reference

to the recent works in India.

Of the many growth regulators now available, the influence of indole acetic acid on plant growth was perhaps the most exhaustively studied. Its effects in increasing the germination percentage, in improving the vigour of the plant and yield have been studied by numerous workers. Various methods of application of hormones have been employed by different workers. During the decade 1930-1940 numerous reports have been made concerning the treatments of seeds with growth promoting substances. The results obtained have varied from harmful to beneficial effects. The works of Cholodny (1936) Grace (1937-41) Thimann and Lane (1940) claiming beneficial effects deserve a special mention.

In the various efforts made to increase the growth and yield of plants with hormone treatments, the results show that the response of plants varies widely with the species. Friedrich (1940) has reported that the treatment of a variety of vegetables with hormones caused an increase in the root shoot ratios of plants.

To mention a few recent Indian works, Sathyanarayanan (1959) from his studies on the effects of napthalene acetic acid and indole acetic acid on sweet potato found that the fresh weight of plants (tops) in-

creased at all stages of growth.

Shanmugavelu (1960) obtained increase in leaf area, number of leaves and dry weight in tobacco when treated with indole acetic acid and indole butyric acid.

Chatterjee (1960), using indole acetic acid, indole butyric acid, ascorbic acid and naphthalene acetic acid, reported beneficial effects of these hormones in increasing the growth of tung oil nuts.

Ganapathiappan (1960) in his studies on the effect of plant hormones on Coleus parviflorus noted that fresh weight of tops and tubers were increased by use of indole acetic acid, indole butyric acid and naphthalene acetic acid.

Kumara Pillay (1962) has reported positive results in an attempt to increase the percentage of germination of different hard and soft coated vegetable seeds using natural hormones like coconut milk, cow's urine etc. But all the synthetic hormones, indole acetic acid, indole butyric acid and naphthalene acetic acid used at a concentration of 0.02%, were found to inhibit germination.

For the last few years more and more workers in the field of hormone physiology have been giving

attention to gibberellic acid. The most striking and typical plant response to treatment with gibberellic acid is stem elongation. Brian and Hemming (1955) have reviewed the works till 1955. They reported the effect of gibberellic acid on the growth of 14-day old pea seedlings. There was appreciable increase in growth, height and weight of dwarf varieties. Phinney (1956) has reported that dwarf maize plants assumed their normal phenotype by treatment with gibberellic acid. Bonde and Moore (1959) also found that the stems of dwarf peas elongated at a single application of gibberellic acid at concentrations of 0.0015 to 15 mg/l. Greater effect was obtained with seedlings of 20-days age, than with those of 10-days of age. Rappaport (1957) found elongation of stem in 4-6 leaved young plants of tomato by gibberellin application. Chakravarti (1958) experimenting on the effect of gibberellic acid on Sesamum indicum at concentrations of 1, 10 and 100 ppm. found that height was increased.

The effect of gibberellic acid on Hibiscus cannabinus, Corchorus olitorius and other plants was tested by Stant (1959). All plants showed increase in height, inter-node number and inter-node length. Soost (1959) found an increase in the height of a dwarf variety

of tomato along with a tall variety, when 30-60 u gm. of gibberellic acid was applied to the fourth expanding leaf. The elongation was effected below the point of application of the hormone.

Randhawa and Singh (1959) reported that height and other growth characters were increased by the use of gibberellic acid on citrus seedling root stocks. 100 ppm. gave the maximum increase in height of 71.4% over control.

Shimokava and Adachi (1960) studied the effect of gibberellic acid on Cryptostoemia japonica using concentrations of 25, 50 and 100 ppm. It was found that the earlier the treatment, the greater was the effect. Maximum elongation was obtained at the 100 ppm. concentration.

Cajlahjan (1960) using gibberellic acid at 0.001% to 0.01% concentrations increased height in hemp and tobacco plants. About 250% increase in height over control was recorded for tobacco. Narasimhan (1960) also found that height of tobacco plants increased with gibberellic acid application.

Yermanos and Knowles (1960) observed stem elongation in Safflower by gibberellic acid treatment. 10 and 100 ppm. concentrations were used at different

stages of development. At all stages the investigators got increase in height of the plant. Dransfield (1961) has recorded elongation of stem in cotton by use of gibberellic acid. Appala Naidu (1961) has reported stem elongation in ragi using gibberellic acid.

Many investigators have used gibberellic acid as pre-sowing treatments of seeds with a view to improving germination and subsequent growth of the seedling plants. De Leon and Derafols (1959) studied the effect of gibberellic acid on germination of seeds of Kok-saghyz. They found that the effect was maximum at 5 ppm. concentration and it became progressively less marked as the concentrations were increased, and was comparatively slight when 7, 8, 9 and 10 ppm. were used. They got similar results with broad beans also.

Doxtator (1958), when treated sugar beet seeds with gibberellic acid at 10, 100 and 1000 ppm. concentrations, could not find any effect on germination. So also Lawson (1958) could not establish any significant difference between treated and untreated seeds in the root weight and sucrose content.

Pieri (1958) reported that, following pre-sowing treatments of vine seeds for 10-day duration with different concentrations of gibberellic acid, the seeds

treated with 10 ppm. grew faster than controls for about 9 months, but the controls overtook them by growth after that period. Nichols (1957, 58 and 59) noted elongation of stem in cocoa seedlings by use of gibberellic acid. But the seedlings became weak as a result of the treatment. Filippenko (1960) showed that soaking of grape seeds in gibberellic acid solution did not affect seedling growth but application at cotyledon stage increased height.

Several workers have reported improvement of plants by gibberellic acid treatments. Corns (1958) recorded higher yield of forage crops by the use of gibberellic acid. Bonde and Moore (1959) in dwarf peas, and Randhawa ans Singh (1959) in citrus seedling root stocks have recorded increased weight of plants.

Spina (1960) reported the effect of gibberellin on sour orange, vine and fig. Young sour orange plants treated with gibberellic acid at 50 ppm. 3 times at 10-day intervals were temporarily stimulated to grow faster than the controls, but by 30 days after the first treatment there was no difference between the two groups.

Jauhari et al., (1960) treating spinach (Spinacea oleracea) plants with gibberellic acid at 0, 10, 25, 50 and 250 ppm. concentrations at 40, 55 and 70

days after sowing, found that foliar sprays of lower concentrations of gibberellic acid like 10 ppm. can be conveniently used for increased production of the crop.

The response of leaf area and leaf number by application of gibberellic acid has received the attention of many investigators. Yabuta and Hayashi (1939) found that gibberellic acid slightly inhibited the leaf expansion in tomato, morning glory and cucurbits, while the leaf number showed an increase in cucumber, it remained the same in the other two plants.

Yabuta et al., (1941) got smaller number of leaves which were paler compared to controls in tobacco plants treated with gibberellic acid. But the largest single leaf was obtained from treated plants, which was almost double the size of control leaves. Yabuta, et al., (1943) got larger leaf number and leaf area in tobacco plants followed by gibberellic acid treatment. Narasimhan (1960) on the contrary recorded no increase in leaf area in tobacco plants treated with gibberellic acid.

Yogeswari (1948) reported that tea plants sprayed with 100 mg./L gibberellic acid after the first plucking gave 28% increase in number and 58% increase in weight of leaves. However,in another experiment the same author reported that the

number and fresh weight of leaves to have slightly reduced.

Kato (1953) found that leaf area was reduced in short term experiments with gibberellic acid in sunflower and soyabean.

Lockhart (1956) observed that there was no effect for gibberellic acid as far as leaf expansion is concerned in pea leaves in the presence of light.

Phinney and West (1961) found that the effect of hormones on the shape and size of leaves varies according to the developmental pattern of the leaf. According to this view leaves of grass having intercallary meristem grows in length while leaves of dicots grow in breadth also.

Brian et al., (1954) have recorded a small increase in leaf in wheat and peas with gibberellic acid treatment. Randhawa et al., (1959) have noted slight increase in leaf area in citrus seedlings with gibberellic acid.

Investigations on the mechanism of elongation of internodes in response to gibberellic acid treatment have been made by various workers. Wada (1948) from his studies on the effect of gibberellic acid on the staminal hairs of Tradescantia concluded that there was no effect on cell division even at levels toxic to the rice plant. Imura (1940) and Hayashi et al., (1953) concluded that cell division was insignificant and they attributed the effect to cell elongation. Brian et al.,

(1954) also have demonstrated that cell elongation was sufficient to explain the stem elongation observed in pea.

Yabuta and Hayashi (1939) also noted cell elongation as an effect of gibberellic acid but they think that cell division also might have occurred.

Greulach and Haesloop (1958) on the other hand held that growth promotion by gibberellic acid involved only cell division and not cell elongation, and that in the pith, gibberellic acid might also have influenced the phase of cell division. He also suggested the necessity for revaluation of the earlier conclusions on cell enlargement.

Dransfield (1951) recorded that gibberellic acid treatment increased the circumference in the lower internodes and reduction in upper internodes. Sircar and Chakravarti (1960) found that the circumference of jute plants, increased one week after spraying gibberellic acid. Appala Naidu and Sathyanarayana murthi (1962) noted that gibberellic acid decreased the thickness of Hibiscus canabinus var. purpureus and slightly increased girth in H.canabinus var. vulgaris.

The effect of gibberellic acid has been tested on root production also. Hayashi et al., (1953)

have found inhibition or no effect on root growth. Brian et al., (1954) have obtained consistent decrease in root weight in treated peas and wheat especially in short term experiments of 3 weeks duration. Markiewicz (1960) has found from his studies on the effect of gibberellic acid on a few medicinal plants, that in Vinca rosea root weight was increased when additional manures were supplied along with gibberellic acid.

Number of branches produced also has been observed to have variously affected by application of gibberellic acid. Rao et al., (1960) report that tiller production was significantly reduced in sugarcane. Phinney and West (1961) suggested that gibberellic acid inhibits lateral bud development and consequently lateral branches also. So also Atal and Sethi (1961) reported that branching was much inhibited in hemp plants by the use of gibberellic acid.

But contradictory results were obtained by Brian (1955) as he found that applications of gibberellic acid to decapitated pea seedlings stimulated lateral growth. He also got increased number of branches in cupid sweet pea. Fischnich et al., (1959) recorded increased number of stolons in potato and Narayanan and Vasudeva Menon (1960) obtained increase in the number of tillers in paddy and ragi by use of gibberellic acid.

Appala Naidu and Sathyanarayana murthy (1962) found that in mesta plants when shoot elongation was effected by gibberellic acid treatments the number of branches also increased. In higher concentrations vegetative branches arose in place of flower buds.

Several reports on the effect of gibberellic acid on the flowering and fruiting of plants are available. Early reports by Japanese workers state that 'Bakane' disease causes early flowering. Lang (1956) reports that biennial varieties Hyocyamus, Silene and Samolus could be brought to flowering early by gibberellic acid. Marth et al., (1956) tried gibberellic acid on several flowering plants and found that flowering was induced.

Wittwer and Bukovac (1957) reported that gibberellic acid is 500 times as effective as indole acetic acid in inducing parthenocarpy. Brian et al., (1959) obtained an increase in the number of flower buds in Cupid Sweet peas by weekly sprays of gibberellic acid.

Appala Naidu and Sathyanarayana murthi (1962) found no significant effect on flowering of Hibiscus sabdariffa plants by using gibberellic acid while flowering was delayed in Hibiscus cannabinus.

Chakravarti and Abraham (1958) are of the view that gibberellic acid has no florigenic property

but it brings about an early cessation of vegetative cycle in certain annual and biennial plants.

Randhawa et al., (1959) showed that gibberellic acid coula increase the total yield by 19.6% when used at 40 ppm. concentration as foliar sprays on phalsa. Weaver and McCune (1959) conducted experiments to study the effect of gibberellic acid on three seedless varieties of grapes. The treatments increased the diameter of the berries but did not alter the shape of the curves. In some varieties the treated portions only responded, while the other varieties showed little response. Krishnamurthi et al., (1959) while working on the effect of gibberellic acid on Pusa seedless variety of grapes found that treatments improved berry size as well as quality.

Many workers have reported that gibberellic acid produces chlorosis and other abnormalities. Branas and Vergnes (1960) found that gibberellic acid produced chlorosis, fruit drop and formation of some small seedless berries in vines.

It has been proved that gibberellic acid and other hormones occur naturally in plants. Radley (1958) obtained gibberellin-like substances from the extracts of dwarf and tall pea seedlings. He is of opinion that

these substances native to the plant are responsible for the differential response of varieties to hormones.

Thus the occurrence of these substances as natural hormones in plants and the knowledge accumulated on the synergistic effect of such different endogenous substances make it all the more necessary to further the investigation in order to study the effects of their external application in different species and varieties of plants. In the present investigation, effect of synthetic auxins and gibberellic acid on a leafy vegetable, Amaranthus gangeticus L. is investigated.

MATERIALS AND METHODS

MATERIALS AND METHODS

I. Seed material:

Amaranthus (*Amaranthus gangeticus* L.) seeds of good quality were procured from Central Travancore. They were tested for viability and germination percentage before being used in the experiment. Effect of growth regulators on the growth and yield of Amaranthus was investigated.

II. Growth substances tried:

1. Gibberellic acid (Material manufactured by BDH, Laboratory Chemicals Division, Poole, England).

2. Indole acetic acid (Manufactured by L. Light and Co., Ltd., Colnbrook, England).

3. Indole butyric acid (From L.Light and Co., Ltd., Colnbrook, England).

III. Design of experiment:

The aim of the experiment was to study the effect of the above three plant growth substances on growth and morphological characters. Three concentrations and three different modes of application were tried.

FIGURE I

LAY OUT PLAN OF THE EXPERIMENT

Design - Randomised Block

Replication - Four

Blocks - Four

No. of plants per plot (Pot) - One

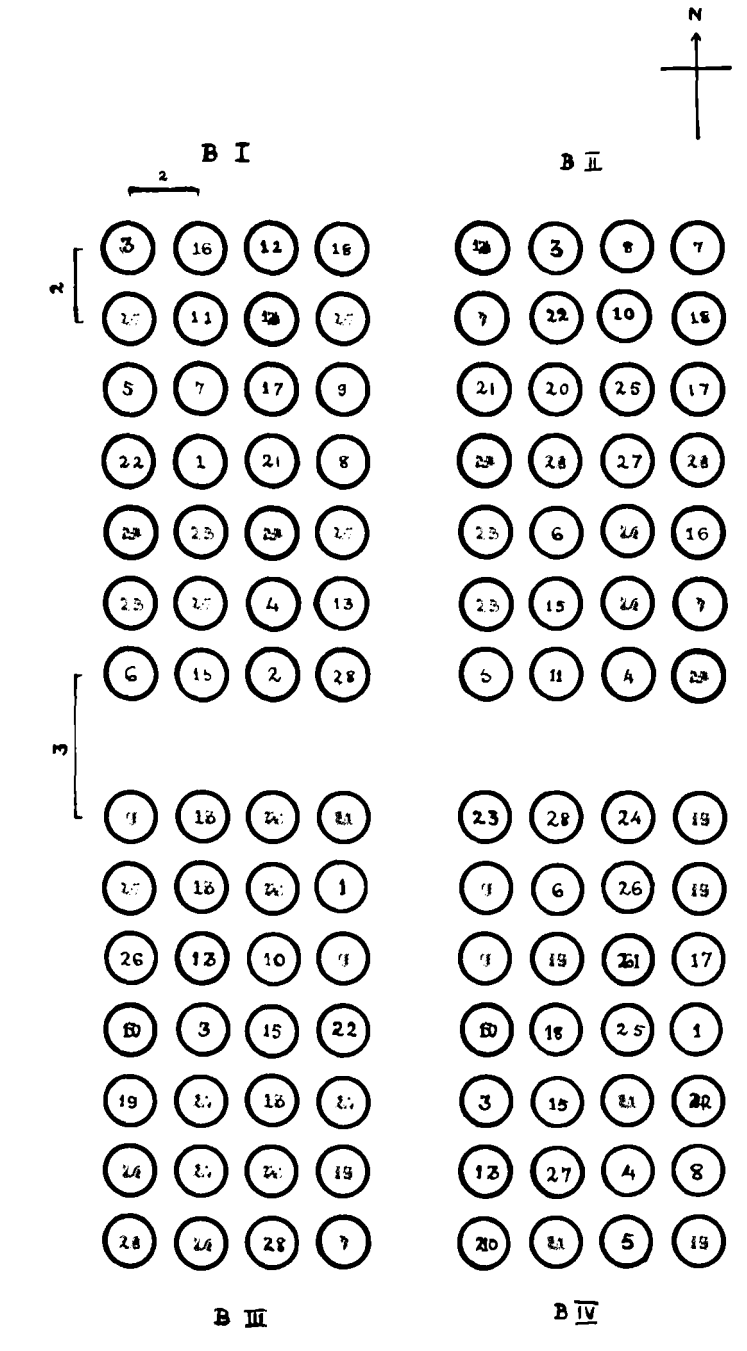


Fig 1 LAY OUT PLAN OF THE EXPERIMENT

The seeds were sown in pots of uniform size 1' x 1' on 12-3-1963. Concentrations used were 10 ppm. and 20 ppm. and 30 ppm. in all cases. The three methods of application were as follows:-

1. Seed treatment only
2. Seed treatment plus one foliar spray, at seedling stage
3. Two foliar sprays only.

Thus there were 28 treatments including control. Details of treatments are given below:

Treatment No.	Chemical.	Concentration.	Method of application.
1	GA	10 ppm.	Soaking of seeds for two hours.
2	GA	20 ,,	,,
3	GA	30 ,,	,,
4	IAA	10 ,,	,,
5	IAA	20 ,,	,,
6	IAA	30 ,,	,,
7	IBA	10 ,,	,,
8	IBA	20 ,,	,,
9	IBA	30 ,,	,,
10	GA	10 ,,	Pre-sowing treatment plus one foliar spray

11	GA	20 ppm.	Pre-sowing treatment plus one foliar spray.
12	GA	30 ,,	,,
13	IAA	10 ,,	,,
14	IAA	20 ,,	,,
15	IAA	30 ,,	,,
16	IBA	10 ,,,	,,
17	IBA	20 ,,	,,
18	IBA	30 ,,	,,
19	GA	10 ,,	Two foliar sprays on 20th and 35th day after planting.
20	GA	20 ,,	,,
21	GA	30 ,,	,,
22	IAA	10 ,,	,,
23	IAA	20 ,,	,,
24	IAA	30 ,,	,,
25	IBA	10 ,,	,,
26	IBA	20 ,,	,,
27	IBA	30 ,,	,,
28	Control		Seeds soaked in distilled water and two water sprays - one on the 20th day and the other on the 35th day.

A randomised Block Design with four replications was adopted, the lay out plan of which is given in figure 1.

IV. Experimental procedure:

Filling of pots:

The required number of earthern plant pots of size 1' x 1' were used. River sand, red earth and compost were mixed in equal proportions (1:1:1) for preparing potting mixture. Equal quantities of the mixture were provided for each pot. The pots were watered for five days before sowing.

Preparation of hormones:

A stock solution was prepared by dissolving the chemical first in rectified spirit and adding the required quantity of distilled water.

Methods of application of hormones:

Method I. Seed treatment:

Fifty seeds each were tied up in cloth pieces and kept soaked in the respective harmone solutions for a duration of two hours. After this period they were taken out, washed thoroughly in distilled water and sown in the respective pots. Seeds soaked in distilled water were used for controls as well as those having no hormone treatments.

Method II. Seed treatment plus one foliar spray:

Seeds were treated as for the first method described above and the foliar spray was given on the 20th

day of sowing (2-4-1963). The plants were sprayed with hormones with an atomiser, until the whole plant surface got uniformly wet. All other pots receiving no hormone treatments were sprayed with distilled water including control.

Method III. Two foliar sprays:

Seeds were soaked in water for two hours before sowing. The two sprays were done on the 20th and 35th day of sowing. Plants under the 1st method of treatment were sprayed, along with controls, with distilled water.

Ten seeds each of treated and untreated seeds were sown in each pot. Sowing was done on 12-3-1963. After a week of sowing all seedlings were chopped off leaving only one average sized healthy plant in each pot.

Watering was done twice a day. Equal quantities of water was supplied to each pot as far as practicable. Care was taken not to wash off the hormones when watering, on the days following the hormone sprays.

Method of recording observations

The following characters were recorded for investigation.

1. Height of plants
2. Number of leaves
3. Leaf area (sample of 3 leaves from each plant)
4. Number of branches
5. Total length of branches
6. Girth of main stem at a particular internode
7. Date of flowering
8. Fresh weight of plants

(1) Height of plants:

Regular observations were recorded at 5-day intervals from the 10th day of sowing till harvest. Data for the 30th day and 50th day were statistically analysed. Height was measured from ground level to the tip of the terminal bud.

(2) Number of leaves:

Observations of number of leaves on the main stem also were taken at 5-day intervals. Data for the 30th and 50th day were statistically analysed. In counting, the very small leaves were discarded.

(3) Leaf area:

The leaf area for 8th, 13th and 18th leaves was measured. The leaves were traced on graph paper for measurement.

(4) Number of branches:

Number of branches of each plant was counted at the time of harvest.

(5) Total length of branches:

This was measured at the time of harvest.

(6) Girth of main stem at a particular internode:

This was also measured at the time of harvest. The 4th internode was selected in all plants for measurement.

(7) Date of flowering:

Date of flowering was recorded for each plant when the first inflorescence appeared.

(8) Fresh weight of plants:

The tops were cut off at ground level and the weights were recorded immediately by using a counterpoise balance. Roots were taken out separately by inverting the pots and washing off the soil. The total weight of shoot and root in each case was taken as the fresh weight of the whole plant.

Harvest was conducted on 65th day (16-5-'63).

RESULTS

EXPERIMENTAL RESULTS

Data on the effect of treatments on the height of plants, number of leaves, leaf area, number of branches, total length of branches, girth of the main stem at a particular internode, fresh weight of plants and the date of flowering as recorded and analysed statistically are given below:

I. Height of plants

The analysis of variance (Table I) shows that no significant difference in height was effected by the various treatments mentioned elsewhere, independent of the method of treatment adopted. Thus pre-sowing treatment or pre-sowing treatment followed by a foliar spray on the 20th day, or a single foliar spray alone on the 20th day (the plants under the third method of treatment get only one spray by the 30th day after planting) after sowing with the various hormonal solutions according to the need of the experiment, could not induce any significant increase in the height of the plants.

TABLE I

Analysis of variance for height of plants on the 30th day of sowing

Source.	Sum of squares.	d.f.	Variance.	F.	Inference
Total	682.69	111			
Blocks	21.22	3	7.07	1.09	Not significant
Treatments	137.88	27	5.16	0.80	Not significant
Error	523.59	81	6.49		

Critical difference = 3.58

Standard error = 1.27

Regarding the height of plants on the 50th day all the treatments under the three methods of application failed to bring about any significant difference over control (Table II).

TABLE II

Analysis of variance for height of plants on the 50th day after sowing

Source.	Sum of aquares.	d.f.	Variance.	F.	Inference.
Total	2158.00	111			
Blocks	93.88	3	31.29	1.50	Not significant
Treatments	399.20	27	14.80	0.72	Not significant
Error	1665.92	81	20.55		

Critical difference = 6.375

Standard error = 2.267

Height of the plants under the various treatments as recorded at the time of harvest also did not show any significant difference compared to control (Table III).

TABLE III

Analysis of variance for height of plants at the time of harvest

Source	Sum of aquares.	d.f.	Variance.	F.	Inference.
Total	6126.50	111			
Blocks	477.18	3	159.06	2.86	Not significant
Treatments	1147.25	27	42.49	0.76	Not significant
Error	4502.17	81	55.58		

Critical difference = 10.49

Standard error = 3.72

Thus it was observed that none of the hormones, irrespective of the concentrations or the method of application adopted, was capable of producing any significant increase in the height of plants.

II. Number of leaves

Number of leaves on the main stem as recorded on the 30th day, after analysis of the data, revealed that the results did not show any increase in the number of leaves over control (Table IV).

TABLE IV

Analysis of variance for the number of leaves

On the main stem on the 30th day

Source.	Sum of aquares.	d.f.	Variance.	F.	Inference.
Total	127.56	111			
Blocks	12.81	3	4.27	4	Not significant
Treatments	22.81	27	1.06	1	Not significant
Error	85.54	81	1.06		

Critical difference = 1.45

Standard error = 0.514

The data on the number of leaves on the main stem on the 50th day, on statistical analysis showed that there was significant difference between treatments. The analysis of variance table is given below (Table V).

TABLE V

Analysis of variance of number of leaves on the main stem on the 50th day

Source.	Sum of aquares.	d.f.	Variance.	F.	Inference.
Total	323.56	111			
Blocks	4.10	3	1.37	1	
Treatments	119.81	27	4.44	1.8	*
Error	199.65	81	2.46		

*Significant at 5% level.

Critical difference = 2.2

Standard error = 0.78

There was no significant increase when the 1st method of application was followed.

In the second method of application (pre-sowing treatment followed by one foliar spray) it was found that gibberellic acid and indole butyric acid at 20 ppm. and 30 ppm. concentrations could increase the number of leaves significantly over control while all concentrations of indole acetic acid were comparatively ineffective (Table VI).

TABLE VI

Number of leaves on the main stem on the 50th day following hormone treatments; Second method (two hours pre-sowing followed by foliar spray on the 20th day); Mean of 4 replicates

Treatments	No. of leaves
Control	25.25
GA 10 ppm.	25.75
GA 20 ,,	27.75
GA 30 ,,	27.75
IAA 10 ,,	26.25
IAA 20 ,,	25.75
IAA 30 ,,	25.75
IBA 10 ,,	26.00
IBA 20 ,,	27.50
IBA 30 ,,	27.75

Critical difference = 2.2

The statistical analysis of the data for the third method, however showed that all the hormones used could induce significant increase in the number of leaves at 30 ppm. concentration while the lower concentrations were ineffective (Table VII).

TABLE VII

Number of leaves on the main stem on the 50th day following hormone treatments; Third method (two foliar sprays, on 20th and 35th day)

Mean of 4 replicates

Treatments	No. of leaves
Control	25.25
GA 10 ppm.	24.50
GA 20 ,,	25.25
GA 30 ,,	27.50
IAA 10 ,,	26.25
IAA 20 ,,	25.25
IAA 30 ,,	28.00
IBA 10 ,,	26.25
IBA 20 ,,	26.75
IBA 30 ,,	28.50

Critical difference = 2.2

At the third stage of observations (at the time of harvest), the statistical analysis of the data showed that the total number of leaves of the whole plant differed significantly for the various treatments tried (Table VIII). From further analysis of the sum of squares

for treatment it was found that there was significant difference between the first and second methods of treatment. The difference between concentrations of gibberellic acid was also seen to be significant.

TABLE VIII.

Analysis of variance for the total number of leaves on harvest

Source.	Sum of squares.	d.f.	Variance.	F.	Inference
Total	80438.21	111			
Blocks	2319.99	3	777.33	1.17	
Treatments	24577.71	27	910.29	1.36	*
Hormones with control	4143.00	3	1381.00	2.09	
Modes of application	2477.47	2	1238.74	1.86	
Seed tr.vs. seed tr.+ 1 spray	3245.58	1	3245.58	4.91	*
,, 2 sprays	486.00	1	486.00	0.74	
Seed tr. + 1 spray vs. 2 sprays	1181.67	1	1181.67	1.79	
I Method GA Conc.	2293.17	2	1146.59	1.73	
IAA Conc.	4033.17	2	2016.59	3.05	
IBA Conc.	147.17	2	73.59	0.11	
II Method GA Conc.	1058.17	2	529.09	0.80	
IAA Conc.	1660.17	2	830.09	1.26	
IBA Conc.	1456.14	2	728.07	1.10	
III Method GA Conc.	6652.00	2	3326.00	5.03	**
IAA Conc.	1070.17	2	535.09	0.81	
IBA Conc.	1520.42	2	760.21	1.15	
Error	53540.51	81	660.99		

*Significant at 5% level

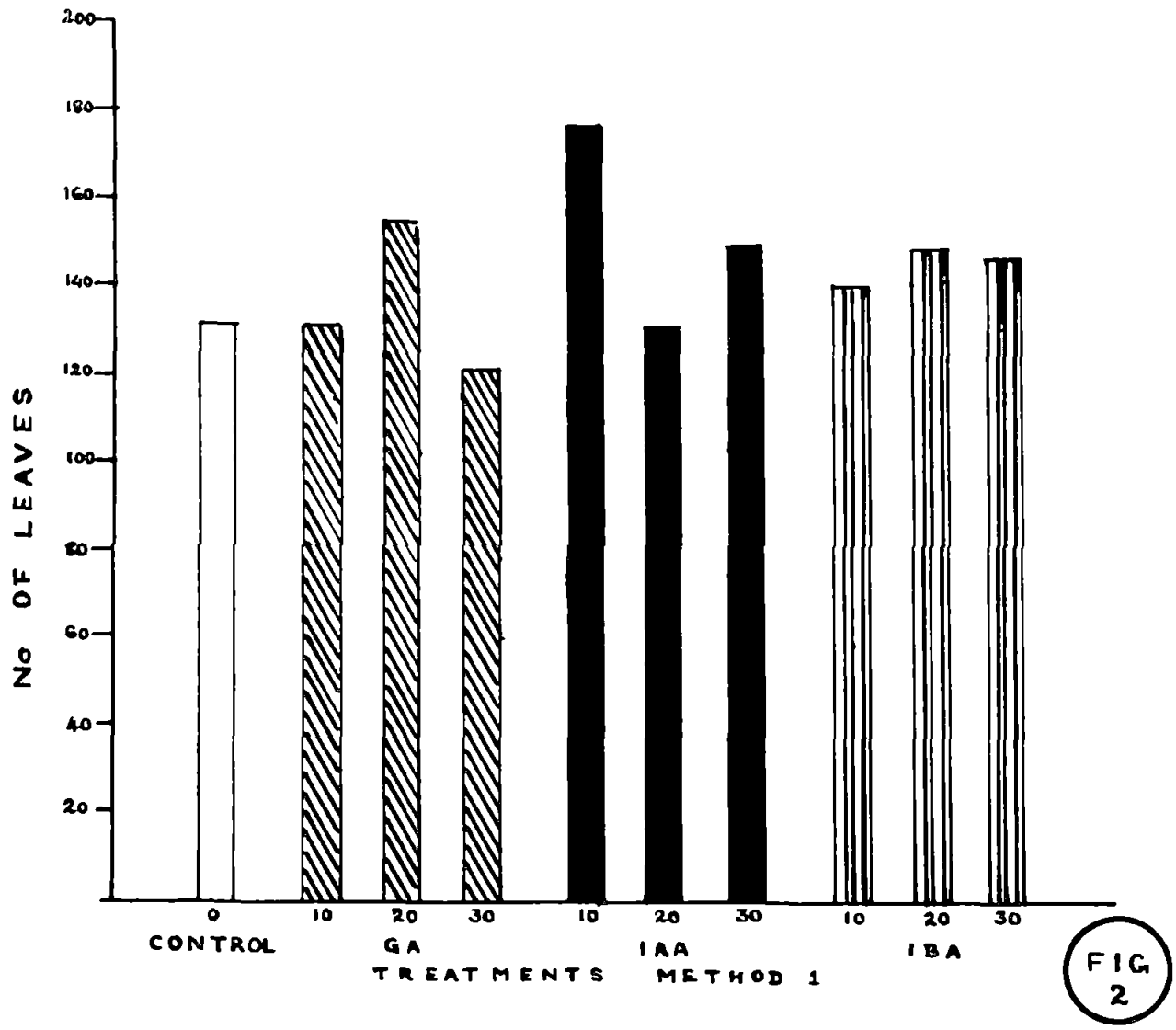
**Significant at 1% level

Critical difference = 36.16

S.E. of means = 12.873

FIGURE 2

Diagram showing the number of leaves at the time of harvest following hormone treatment; First method (Presowing treatment for 2 hours)
(Table IX)


No OF LEAVES
200
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80
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30
10
20
30
10
20
30
CONTROL
GA
IAA
IBA
TREATMENTS METHOD 1

FIG 2

By pre-sowing treatment of the various hormonal solutions, significant increase in the number of leaves was obtained only with indole acetic acid 20 ppm. (Table IX - Figure 2).

TABLE IX

Number of leaves at the time of harvest (65th day) following hormone treatments; 1st Method (2 hour pre-sowing)

Mean of 4 replications

Treatment	No. of leaves
Control	133.00
GA 10 ppm.	135.75
GA 20 ,,	155.00
GA 30 ,,	121.75
IAA 10 ,,	177.75
IAA 20 ,,	133.50
IAA 30 ,,	149.00
IBA 10 ,,	141.75
IBA 20 ,,	150.25
IBA 30 ,,	147.00

Critical difference = 36.16

Indole acetic acid at 30 ppm. and indole butyric acid at 10 ppm. only showed clear difference over control in the second method of treatment (pre-sowing plus one foliar spray on 20th day)as regards number of leaves at the time of harvest Table X - Figure 3 , gives the comparison of treatments with control.

TABLE X

Number of leaves at the time of harvest (65th day) following hormone treatment; 2nd Method (2 hour pre-sowing followed by a foliar spray on the 20th); Mean of 4 replications

Treatments	No. of leaves
Control	133.00
GA 10 ppm.	167.75
GA 20 ,,	156.50
GA 30 ,,	144.75
IAA 10 ,,	145.00
IAA 20 ,,	161.00
IAA 30 ,,	173.75
IBA 10 ,,	171.00
IBA 20 ,,	145.00
IBA 30 ,,	151.75

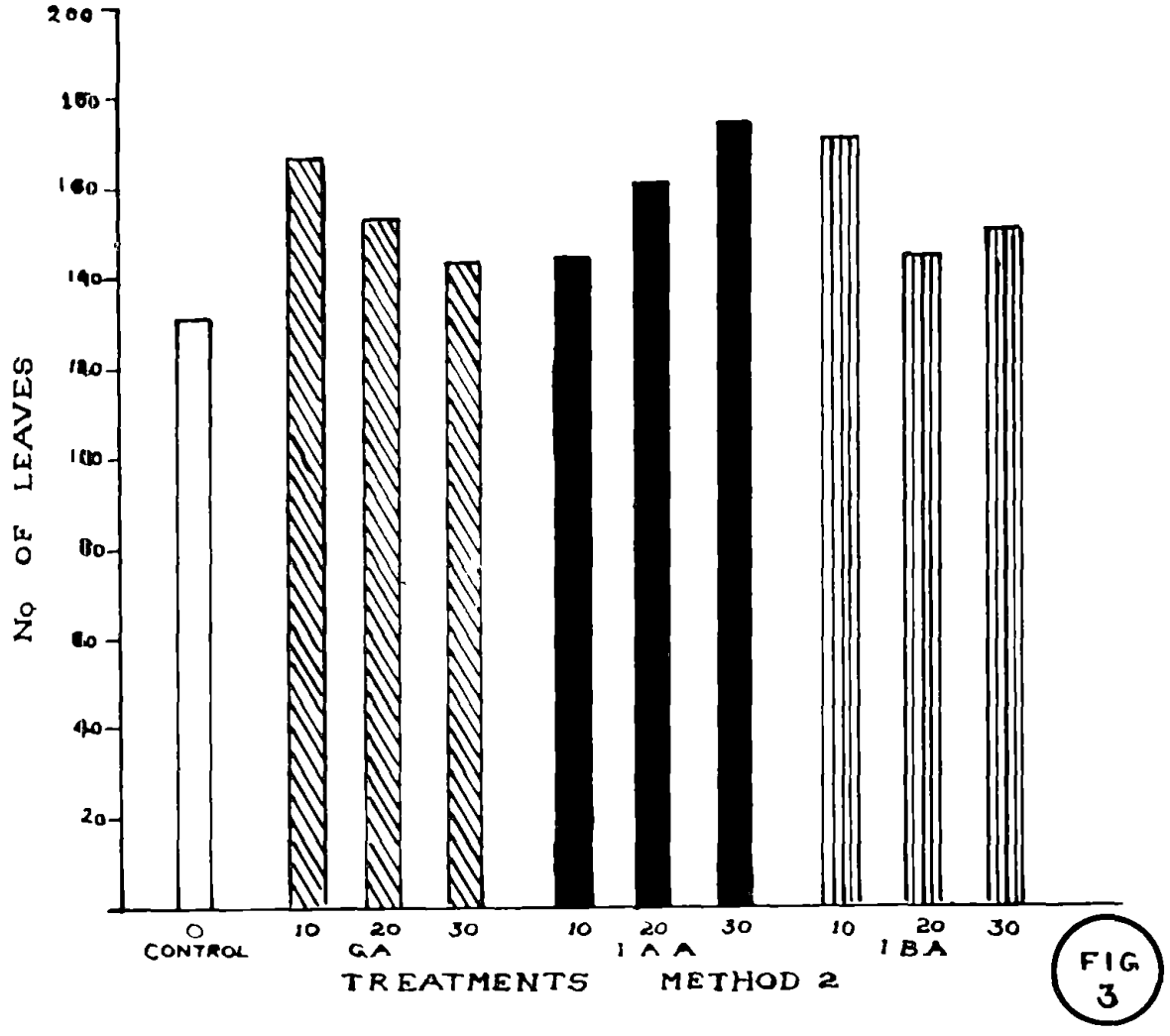
Critical difference = 36.16

FIGURE 3

Total number of leaves at the time of harvest following hormone treatment; Second method (Pre-sowing followed by a foliar spray on the 20th day) (Table X)

FIGURE 4

Total number of leaves at the time of harvest following hormone treatment; Third method (2 foliar sprays on 20th & 35th days) (Table XI)


200
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120
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80
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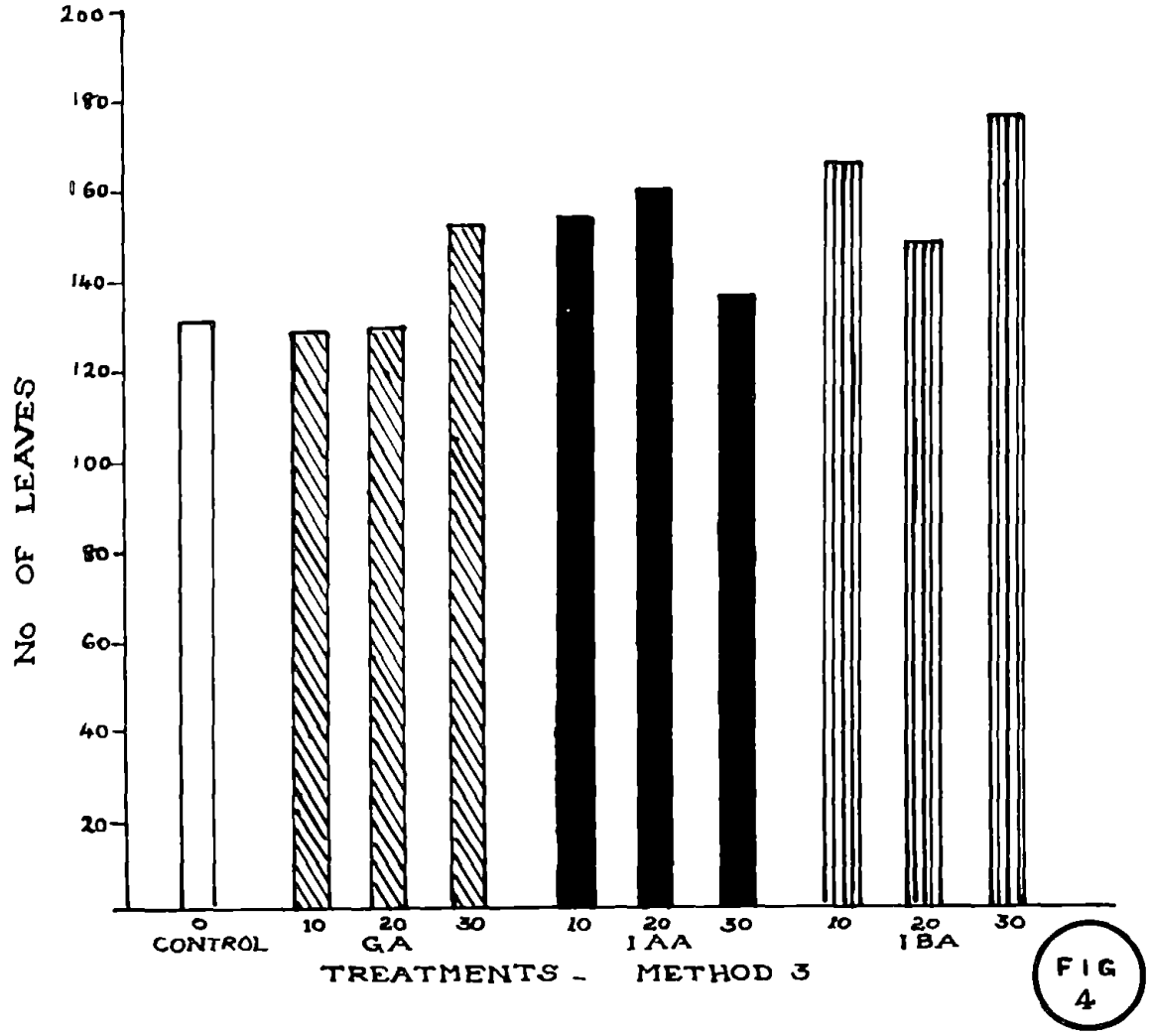
No OF LEAVES
0
CONTROL
10
20
30
GA
10
20
30
IAA
10
20
30
IBA
TREATMENTS METHOD 2

FIG 3


200
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160
140
120
100
80
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40
20
No OF LEAVES
0
CONTROL
10
20
30
GA
10
20
30
IAA
10
20
30
IBA
TREATMENTS - METHOD 3

FIG 4

The data for the third method of treatment as regards the number of leaves on the whole plant at harvest time showed statistical difference over control only when indole butyric acid was used at 30 ppm. (Table XI - Figure 4)

TABLE XI

Number of leaves at the time of harvest (65th day) following hormone treatments; 3rd Method (two foliar sprays on 20th and 35th day); Mean of 4 replicates.

Treatments	Number of leaves
Control	133.00
GA 10 ppm.	129.75
GA 20 ,,	130.25
GA 30 ,,	154.25
IAA 10 ,,	145.50
IAA 20 ,,	160.50
IAA 30 ,,	137.75
IBA 10 ,,	167.00
IBA 20 ,,	149.75
IBA 30 ,,	177.00

Critical difference = 36.16

III. Leaf area

Three leaves from each plant were measured at the time of harvest. The statistical analysis of the data (Table XII) showed that there was no significant difference between treatments and control. Therefore none of the hormones at the levels and the method of applications tried were found to be effective in increasing the leaf area.

TABLE XII

Analysis of variance for leaf area

Source.	Sum of aquares	d.f.	Variance.	F.	Inference
Total	79667.68	111			
Blocks	10480.03	3	3493.34	4.46	
Treatments	7808.68	27	28.80	1	Not significant
Error	61378.97	81	757.76		

Critical difference = 38.6

Standard Error = 13.8

IV. Total number of branches per plant

The analysis of variance(Table XIII)showed that the treatments differ significantly in respect of the number of branches as recorded at the time of harvest. It is found from further comparison that there is significant difference between concentrations of indole acetic acid and its influence on the production of branches.

TABLE XIII

Analysis of variance for number of branches at the time of harvest

Source	Sum of squares	d.f.	Variance.	F.	Inference
Total	287.00	111			
Blocks	10.32	3	3.44	1.51	
Treatments	92.25	27	3.42	1.51	*
Hormones and Control	5.36	3	1.79	0.79	
Mode of application	11.80	2	5.90	2.6	
Seeds vs. seed + 1 spray	11.63	1	5.82	2.55	
Seed tr. vs. 2 sprays	2.00	1	2.00	0.88	
Seed tr. vs. 2 sprays + 1 spray	4.03	1	4.03	1.77	
I Method GA Conc.	6.17	2	3.09	1.34	
IAA ,,	12.67	2	6.34	2.78	
IBA ,,		2			
II Method GA ,,		2			
IAA ,,	15.50	2	7.75	3.4	*
IBA ,,	2.15	2	1.08	0.43	
III Method GA ,,	8.17	2	4.08	1.79	
IAA ,,	7.17	2	3.59	1.58	
IBA ,,	8.17	2	4.09	1.79	
Error	184.43	81	2.28		

* Significant at 5% level

Critical difference = 2.13

S.E. of mean = 0.75

The analysis of the data showed that the number of branches produced by a plant under the various treatments in the first method of application did not differ significantly over control.

In the second method of treatment (seed soaking followed by one foliar spray on the 20th day) indole acetic acid at 20 ppm. concentration gave significantly higher number of branches (Table XIV).

TABLE XIV

Number of branches at the time of harvest (65th day) following hormone treatments; 2nd Method (2 hour soaking followed by one foliar spray on the 20th day); Mean of 4 replicates

Treatments	No. of branches
Control	17.50
GA 10 ppm.	18.50
GA 20 ppm.	18.50
GA 30 ppm.	18.50
IAA 10 ppm.	16.75
IAA 20 ppm.	19.50
IAA 30 ppm.	17.75

IBA	10 ppm.	19.00
IBA	20 ppm.	18.00
IBA	30 ppm.	18.25

Critical difference = 2.13

By adopting the third method of treatment (2 foliar sprays) indole butyric acid at the highest concentrations used, only gave significantly higher number of branches (Table XV).

TABLE XV

Number of branches per plant at the time of harvest (65th day); following hormone treatment; 3rd Method (two foliar sprays); Mean of4replications.

Treatments		No. of branches
Control		17.50
GA	10 ppm.	14.75
GA	20 ,,	14.75
GA	30 ,,	19.00
IAA	10 ,,	17.50
IAA	20 ,,	17.75
IAA	30 ,,	16.00

IBA	10 ppm.	18.00
IBA	20 ,,	18.00
IBA	30 ,,	19.75

V. Total length of branches

The data on the total length of branches were collected at the time of harvest. Although there was difference between treatments visually, the statistical analysis of the data showed that the differences are not significant (Table XVI)

TABLE XVI

Analysis of variance for total length of branches at the time of harvest

Source.	Sum of square	d.f.	Variance.	F.	Inference.
Total	702700.42	111			
Blocks	16654.31	3	5551.43	1	Not significant
Treatments	208290.67	27	7714.47	1.31	,,
Error	477756.44	81	5898.23		

Critical difference = 108.06

Standard error = 38.42

VI. Girth of Main stem

The fourth internode was measured in all plants at the time of harvest. The data on statistical analysis showed that the girth was significantly influenced by various hormonal applications (Table XVII), Splitting of the treatment sum of squares for comparison of different components, it was seen that the difference of girth produced by harmones compared to control was significant. The three concentrations of gibberellic acid also showed significant difference.

TABLE VII

Analysis of variance for girth of Plants at harvest

(Main stem)

Source.	Sum of squares.	d.f.	Variance.	F.	Inference
Total	4167.56	111			
Blocks	104.45	3	34.82	1.07	Not significant
Treatments	1442.31	27	53.42	1.65	**
Hormones with control	321.92	3	107.31	3.00	*
Mode of application	18.44	2	9.32	0.28	Not significant
Seed treatment vs. Seed treatment + 1 spray	18.00	1	18.00	0.60	,,
Seed tr. vs. 2 spray	9.38	1	9.38	0.27	,,
Seed tr. + 1 spray vs. 2 spray	1.38	1	1.38	0.043	,,
Method I GA Conc.	266.00	2	133.00	4.41	*
IAA ,,	95.17	2	47.59	1.47	Not significant
IBA ,,	24.50	2	12.25	0.38	,,
Method II GA ,,	21.17	2	10.59	0.37	,,
IAA ,,	162.67	2	81.34	2.51	,,
IBA ,,	23.17	2	11.59	0.36	,,
Method III GA ,,	126.17	2	63.09	1.90	,,
IAA ,,	71.17	2	35.59	1.10	,,
IBA ,,	121.17	2	60.59	1.90	,,
Error	2620.80	81	32.36		,,

* Significant at 5% level

** Significant at 1% level

Critical difference = 7.99

S.E. of means = 2.84

The seed treatment of hormones affected the girth of the plants as follows (Table XVIII - Fig.5).

TABLE XVIII.

Girth of plants at the time of harvest (65th day) following hormone treatments; 1st Method (2 hours seed soaking alone); Mean of 4 replicates.

Treatments.	Girth in mm.
Control	56.25
GA 10 ppm.	64.50
GA 20 ,,	69.50
GA 30 ,,	58.50
IAA 10 ,,	68.25
IAA 20 ,,	61.75
IAA 30 ,,	63.00
IBA 10 ,,	64.00
IBA 20 ,,	66.25
IBA 30 ,,	63.25

Critical difference = 7.99

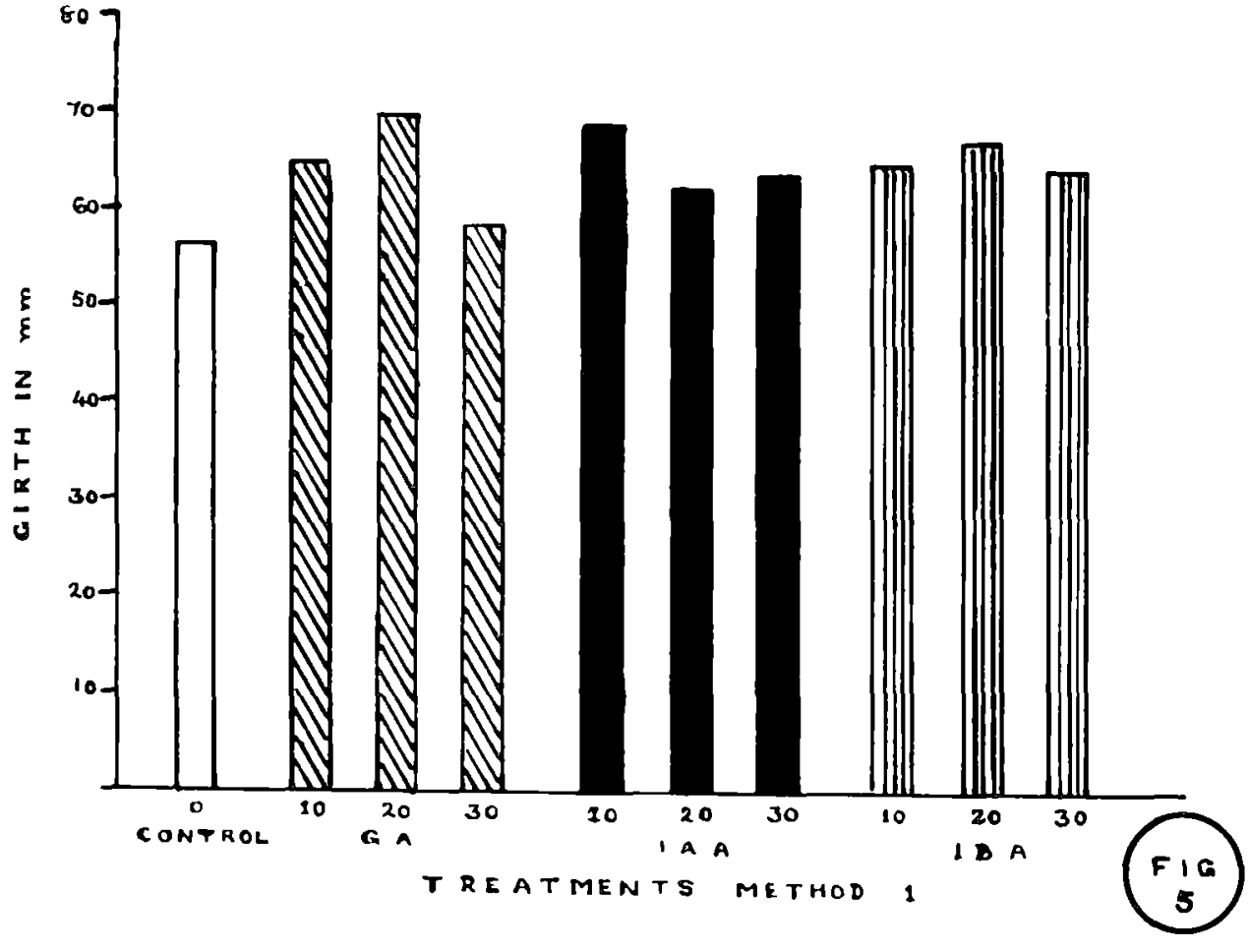
It is seen from the above table that gibberellic acid 10 and 20 ppm., indole acetic acid 10 ppm. and

FIGURE 5

Girth of plants at the 4th internode at the time of harvest, following hormone treatments; First method (Pre-sowing treatment by soaking for 2 hours) (Table XVIII)

FIGURE 6

Girth of plants at the 4th internode at the time of harvest, following hormone treatments; Second method (Pre-sowing treatment followed by one foliar spray on the 20th day) (Table XIX)


80
70
60
50
40
30
20
10
GIRTH IN mm
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CONTROL
10
20
30
GA
10
20
30
IAA
10
20
30
IBA
TREATMENTS METHOD 1

FIG 5

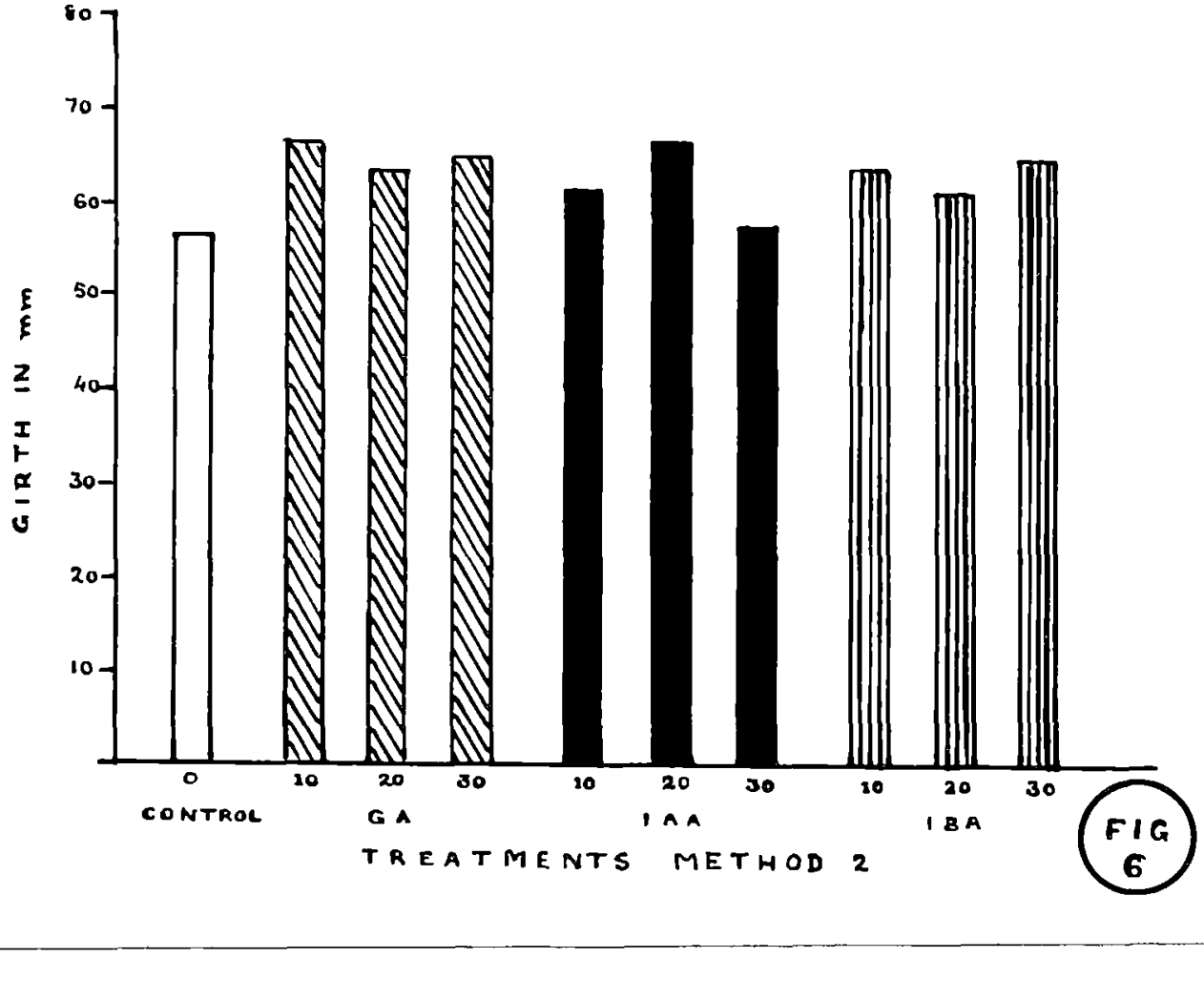

80
70
60
50
40
30
20
10
GIRTH IN mm
0
CONTROL
10
20
30
GA
10
20
30
IAA
10
20
30
IBA
TREATMENTS METHOD 2

FIG 6

indole butyric acid 20 ppm. gave significantly higher girth of plants.

The table below (Table XIX - Fig.6) shows how far the second method of treatment of hormones has influenced the growth in girth of the plants. Gibberellic acid 30 ppm., indole acetic acid 20 ppm. and indole butyric acid at all concentrations gave significant results.

TABLE XIX

Girth of main stem at harvest following hormone treatment; 2nd Method (Seed soaking followed by one spray on the 20th day)

Mean of 4 replicates

Treatments		Girth in mm.
Control		56.25
GA	10 ppm.	66.50
GA	20 ,,	63.25
GA	30 ,,	64.75
IAA	10 ,,	61.75
IAA	20 ,,	66.75
IAA	30 ,,	57.50
IBA	10 ,,	63.75
IBA	20 ,,	61.25
IBA	30 ,,	64.50
Critical difference = 7.99		

FIGURE 7

Girth of plants at the 4th inter-node at the time of harvest, following hormone treatments; Third method (2 foliar sprays on 20th and 35th days). (Table XX)

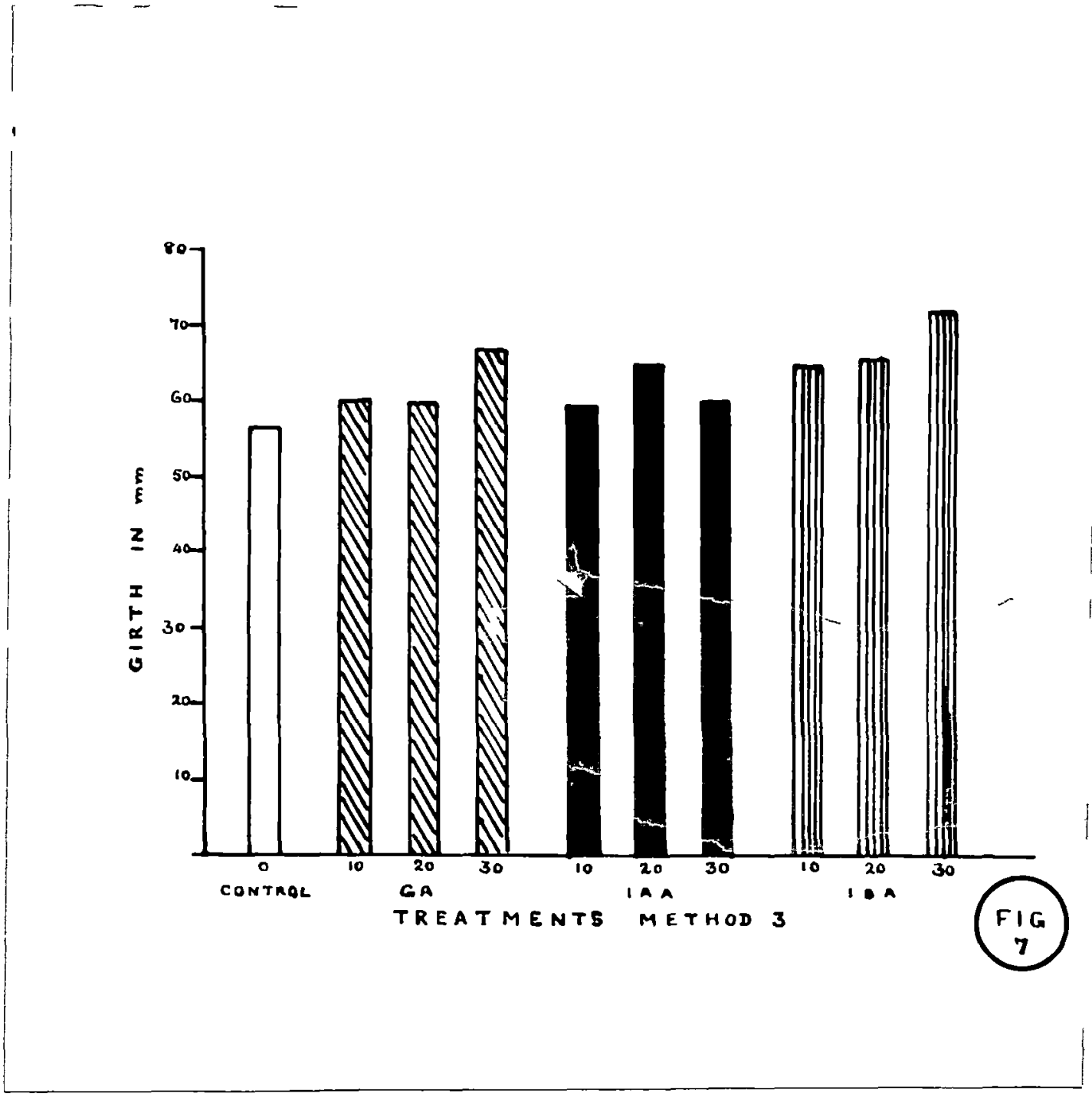

80
70
60
50
40
30
20
10
GIRTH IN mm
0
10
20
30
10
20
30
10
20
30
CONTROL
GA
IAA
IBA
TREATMENTS METHOD 3

FIG 7

By the third method of application of hormones (2 foliar sprays) gibberellic acid 30 ppm., and all concentrations of indole butyric acid tried, gave significant increase (Table XX - Fig. 7).

TABLE XX

Girth of stems at the time of harvest (65th day) following hormone treatments; 3rd Method (2 foliar sprays (on 20th and 35th day); Mean of 4 replicates.

Treatments	Girth in mm.
Control	56.25
GA 10 ppm.	60.00
GA 20 ,,	59.75
GA 30 ,,	66.75
IAA 10 ,,	59.25
IAA 20 ,,	64.75
IAA 30 ,,	60.00
IBA 10 ,,	64.25
IBA 20 ,,	65.55
IBA 30 ,,	71.75

Critical difference = 7.99

VII. Number of days for maturity

The data on the date of maturity (flowering) observed as and when each plant came to flower was analysed statistically and it was found that the various hormones tried, irrespective of the concentrations or the method of applications used, had no significant influence on the flower initiation (Table XXI).

TABLE XXI

Analysis of variance for number of days for maturity

Source.	Sum of squares.	d.f.	Variance.	F.	Inference
Total	274.49	111			
Blocks	9.74	3	3.25		
Treatments	59.74	27	2.21	0.87	Not significant
Error	205.01	81	2.53		

Critical difference = 2.19

S.E. of means = 0.79

VIII. Fresh weight of plants

Fresh weight as recorded immediately after harvest and analysed statistically, showed clearly that there was significant difference between the treatments.

(Table XXII). Further splitting of the sum of squares for treatment it was seen that treatments differed over control and concentrations of gibberellic acid at the pre-sowing method differ significantly between them.

TABLE XXII

Analysis of variance for fresh weight of plants

Source	Sum of squares	d.f.	Variance.	F.	Inference
Total	2914394.42	111			
Blocks	149384.71	3	49461.57	2.62	
Treatments	1238797.17	27	45881.38	2.42 *	
Treatments and control	158215.06	3	52738.35	2.80 *	
Mode of application	53762.31	2	26881.16	1.42	Not significant
Seed tr. vs. seed + 1 spray	48936.06	1	48936.06	2.59	,,
Seed tr. vs. 2 spray	58539.35	1	58539.35	3.10	,,
Seed tr. + 1 spray vs. 2 spray	29265.46	1	29265.46	5.3	,,
Method I GA Con.	257548.17	2	128874.09	6.8	,,
IAA ,,	173707.17	2	86853.59	4.6 **	
IBA ,,	14508.50	2	7254.25	0.38	,,

Source		Sum of squares.	d.f.	Variance.	F.	Inference
Method II	GA Conc.	141371.00	2	70685.50	3.75	Not significant
	IAA ,,	55810.67	2	27905.34	1.48	,,
	IBA ,,	31755.50	2	15877.75	0.84	,,
Method III	GA ,,	37423.17	2	18711.59	0.90	,,
	IAA ,,	29846.50	2	14923.25	0.70	,,
	IBA ,,	17353.17	2	8676.59	0.46	,,
Error		1526212.54	81	18842.13		

* Significant at 5% level

** Significant at 1% level

Critical difference = 193.03

Standard error of means= 68.6

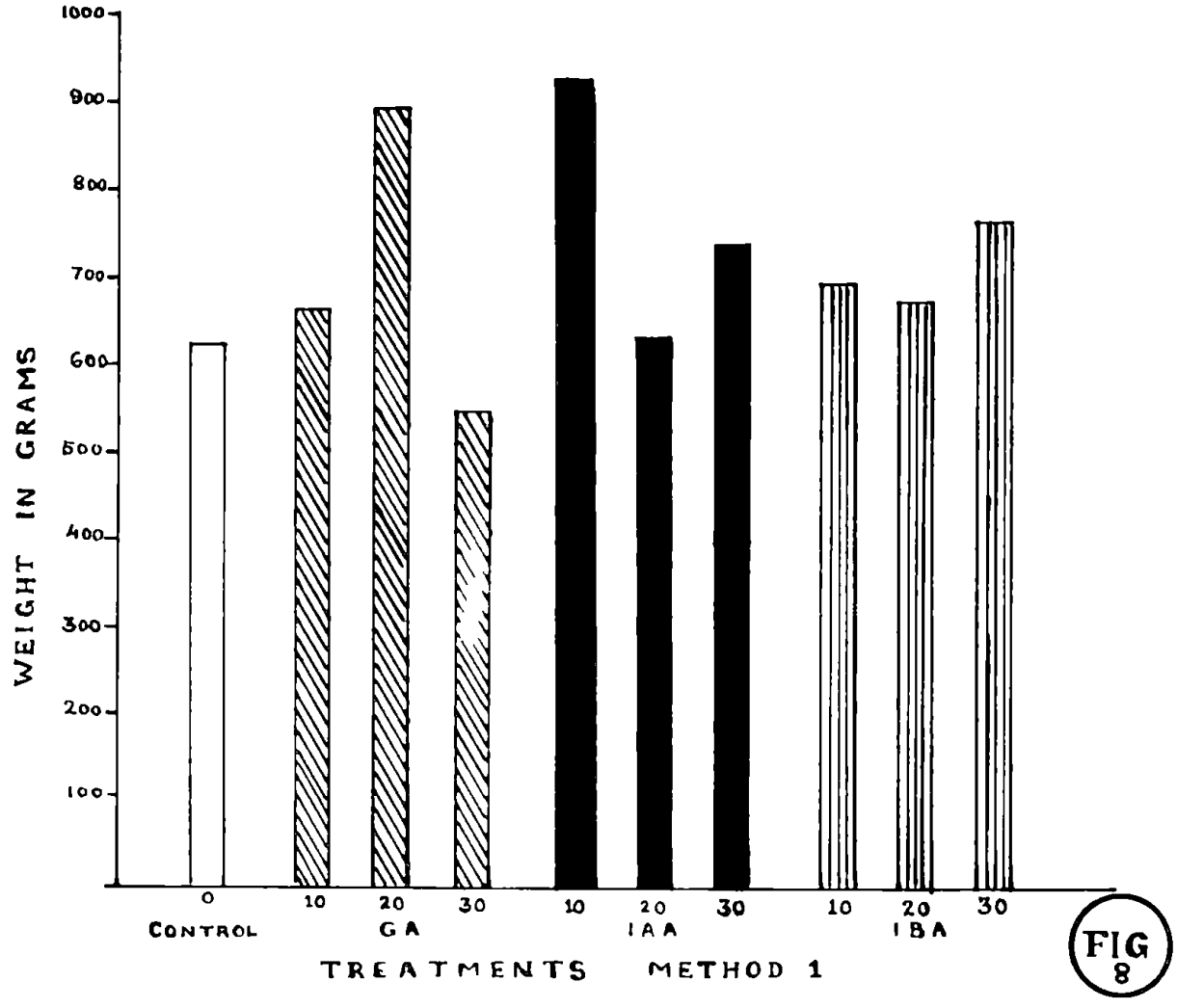
Following the first method of treatment of hormones, gibberellic acid 20 ppm. and indole acetic acid 10 ppm. showed significant increase of fresh weight over control (Table XXIII - Fig. 8)

FIGURE 8

Fresh weight of plants at the time of harvest; following hormone treatments; 1st method (Soaking seeds for 2 hours); (Table XXIII)

FIGURE 9

Fresh weight of plants at the time of harvest; following hormone treatments; 2nd method (Pre-sowing treatments followed by one foliar spray on the 20th day)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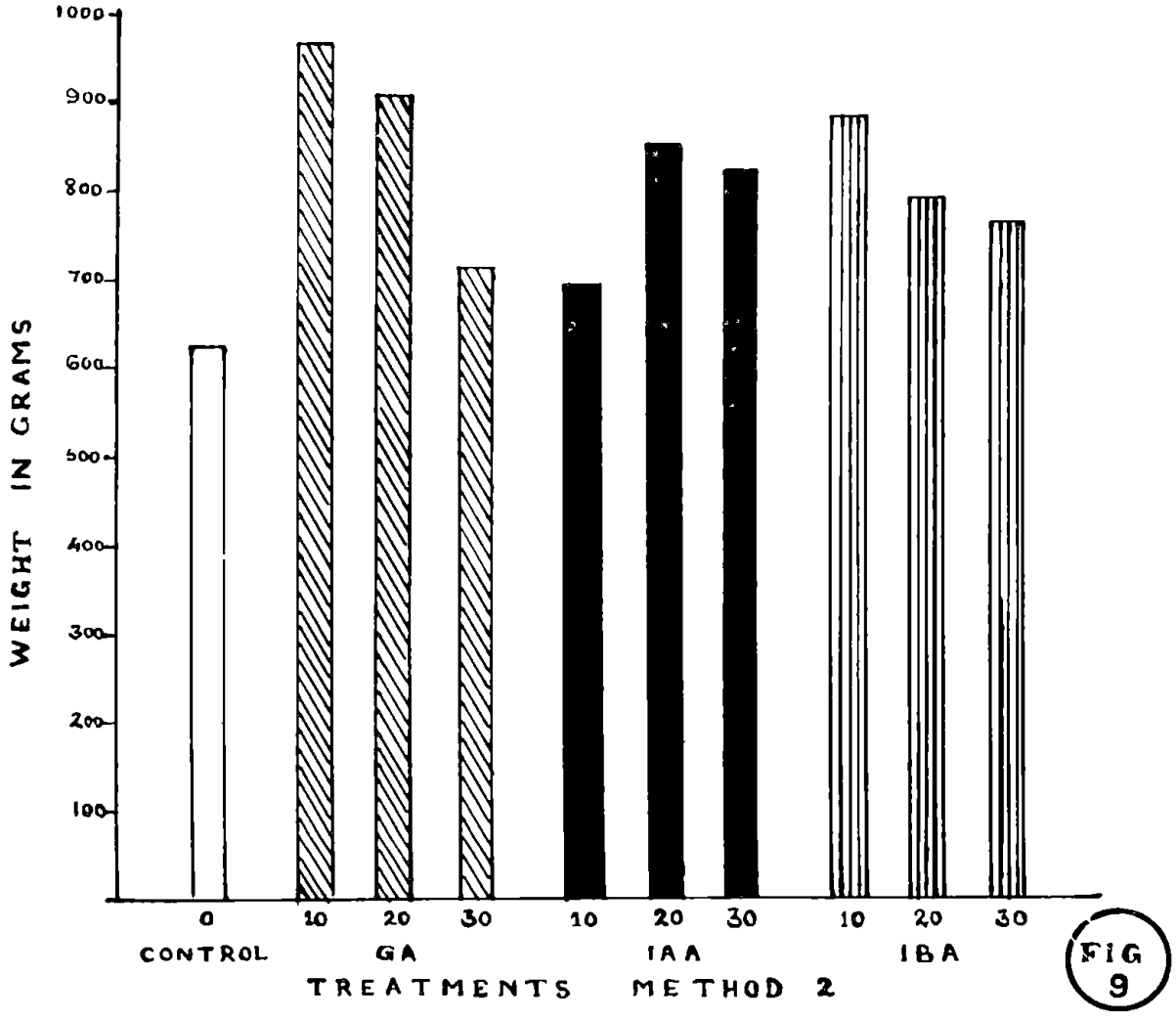
10
20
30
CONTROL
GA
IAA
IBA
TREATMENTS METHOD 1

FIG 8


WEIGHT IN GRAMS
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600
500
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200
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0
10
20
30
10
20
30
10
20
30
CONTROL
GA
IAA
IBA
TREATMENTS METHOD 2

FIG 9

TABLE XXIII

Fresh weight of plants at the time of harvest (65th day) following hormone treatment; 1st Method (seed soaking for 2 hours); Mean of 4 replications

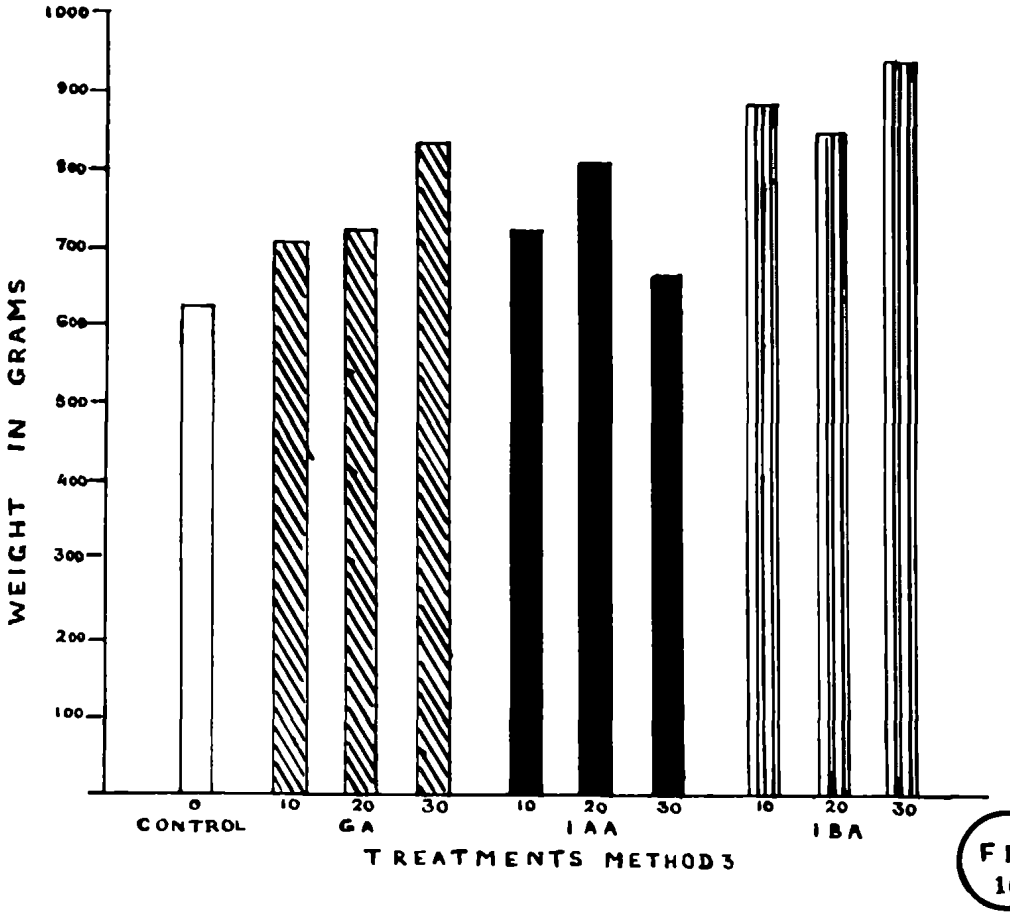
Treatments	Fresh weight
Control	631.75
GA 10 ppm.	669.50
GA 20 ,,	893.25
GA 30 ,,	545.25
IAA 10 ,,	924.25
IAA 20 ,,	634.50
IAA 30 ,,	732.75
IBA 10 ,,	697.50
IBA 20 ,,	774.00
IBA 30 ,,	768.75

Critical difference = 193.03

When the hormones were applied as pre-sowing treatment followed by one foliar spray on the 20th day, gibberellic acid 10 and 20 ppm. indole acetic acid, 20 and 30 ppm. and indole butyric acid 10 ppm. gave significantly higher yield over control. (Table XXIV - Fig. 9).

FIGURE 10

Fresh weight of plants at the time of harvest following hormone treatments; 3rd method (Two foliar sprays on 20th and 35th days) (Table XXV)


WEIGHT IN GRAMS
1000
900
800
700
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500
400
300
200
100
0
CONTROL
10
20
30
GA
10
20
30
IAA
10
20
30
IBA
TREATMENTS METHOD 3

FIG. 10

TABLE XXIV

Fresh weight of plants at the time of harvest (65th day) following hormone treatments; 2nd Method (pre-sowing followed by one foliar spray on the 20th day);

Mean of 4 replicates.

Treatments	Weight of plants
Control	631.75
GA 10 ppm.	966.50
GA 20 ,,	907.50
GA 30 ,,	714.00
IAA 10 ,,	696.50
IAA 20 ,,	852.00
IAA 30 ,,	826.75
IBA 10 ,,	886.75
IBA 20 ,,	797.75
IBA 30 ,,	765.00

Critical difference = 193.03

The hormones applied as two foliar sprays also gave good results. The yields obtained are compared in the table below (Table XXV - Fig. 10). Gibberellic acid 30 ppm. and indole butyric acid at all concentrations showed very good effects.

TABLE XXV

Fresh weight of plants at harvest (65th day) following hormone treatments; third method (two foliar sprays on 20th and 35th day); Means of 4 replicates.

Treatments	Weight of plants
Control	631.75
GA 10 ppm.	708.50
GA 20 ,,	724.75
GA 30 ,,	834.25
IAA 10 ,,	722.25
IAA 20 ,,	810.50
IAA 30 ,,	662.50
IBA 10 ,,	890.50
IBA 20 ,,	853.75
IBA 30 ,,	946.25

Critical difference = 193.03

From the above tables it can be observed that final weight of the plant which is the sum total of all the morphological characters taken together is influenced by all the hormones tried by following one or other of the methods.

D I S C U S S I O N

DISCUSSION

An attempt is made here to discuss the results obtained, in the light of the knowledge gained so far in hormone physiology. From a general observation of the results it appears that amaranthus plant is very sensitive to hormone concentrations and the specificity varies highly with the stage of growth.

Regarding the effects of the hormones tried, on the height of the plant, it is seen from the results that there was virtually no effect. Having a succulent nature, amaranthus can be expected to respond differentially from other plants. Many explanations have been put forward by Galston and Purves (1960), for non-response of plants to auxins:

(a) Prior exposure to unfavourable conditions of light or temperature or anaerobiosis.

(b) Limitation by some other growth factor such as adenine or kinetin.

(c) Prevention of action of auxin or inactivations due to the presence of inhibitors of growth or to auxin-inactiviting systems.

Perhaps the unfavourable conditions prevailed during the course of the experiment might have to some

extent reduced the response of plants to auxin application. As it has been observed by Skoog (1954) that adenine and kinetin may limit the effectiveness of auxin, it is perhaps noteworthy that the presence of ascorbic acid in comparatively larger amounts in amaranthus might have affected the response in a similar way. The findings of a group of Czechoslovak workers are of great interest esepcially in view of the correlation between auxin action and ascorbic acid established by Chinoy et al., (1957) and the Milan group. It is also interesting to note that Marre (1954) presented evidence that ascorbic acid can counteract the effects of auxins.

It appears that the growth response to auxin involves water uptake and other osmotic relations of plant cells. So, the osmotic condition of the cells of any plant may have a bearing on the effectiveness of auxin on that plant.

The permeability patterns, the nature of protoplasmic viscosity and respiratory pathways may all influence the susceptibility of plant cells to hormone applications. But as the basic mechanism by which auxin induces cell elongation is as yet unknown, it is also difficult to attribute the nonresponse of plants to the various treatments tried.

Current thinking emphasizes the importance of the role of auxin in increasing plasticization of cell wall. So the degree of plasticity of the cell wall of a particular plant may influence the effects of auxin.

The observation that this plant did not respond significantly to gibberellic acid is perhaps more interesting. Although the most striking effect of gibberellins is elongation of internode, this has not been a general rule with all plants. It is also known that the response of gibberellic acid is more effective under low nutritional conditions. In the present investigation, however, the plants were grown under high manurial conditions and the general growth was vigorous. Even this might have been a reason for the ineffectiveness of gibberellic acid treatment in enhancing the height of the plants. Instances are reported of the indifference of certain plants and some varieties of a species to applications of gibberellic acid. Appala Naidu (1962) did not get any increase in height in certain varieties of Hibiscus.

Besides the well known examples like tall and dwarf maize shown by Phinney (1956) and cupid sweet pea by Brian and Hemming (1955) for exhibiting differential response, many other such instances have been reported by later workers. The present observation that gibberellic acid was ineffective in promoting shoot growth,

can be attributed tentatively to its varietal characteristics, as well as to the nutrient status of the potting mixture which induced the vigorous growth.

The interaction of applied gibberellin with native auxins and of applied auxins to native gibberellins has a bearing on the ultimate response of the plant. Synergistic interactions of auxins and gibberellins have been reported in several systems. Kuse (1958) has demonstrated that auxin must be present in the petioles of Ipomoea batatas to respond to gibberellin and similar results have been obtained by Brian and Hemming also (1957 and 1958). Hayashi and Murakami (1953) after a series of carefully planned experiments made a suggestion to explain the action of gibberellin in terms of auxin synthesis. If this be true, the presence of ascorbic acid and its known effect in counteracting the auxin action should be considered seriously in any effort to explain non-responsiveness of amaranthus plants to gibberellin. In this connection, it may be worthwhile to mention that gibberellin treatment has been reported to have slightly increased the ascorbic acid content of Soyabeans by Yabuta et al., (1941). Another suggestion made by Brian and Hemming (1958) and Galston and Warburg (1959) that a third factor perhaps an inhibitor, might also be involved in the interaction between gibberellins

and auxins, deserves careful consideration. Appala Naidu and Sathyanarayana murthy (1962) have attributed the absence of response to gibberellic acid, of one of the Hibiscus varieties they studied, to the possibility of the lack of adequate availability or balance of indole acetic acid to work in the three-factor mechanism of shoot growth. It appears that the balance between the active ingredients of these three factors inside the cell determines the nature of response. So, it is tentatively assumed that the biochemical environment brought about by gibberellic acid application in the cells, was not favourable for shoot elongation of the plants under investigation.

The effectiveness of the hormones studied in increasing the number of leaves varied with the method of application followed, as well as with the concentrations used. All concentrations of indole acetic acid failed to increase the number of leaves on the main stem except 30 ppm. applied as two sprays while the total number of leaves was increased when the first and second methods of application were followed.

In the second method 20 ppm. indole acetic acid has also increased the number of branches. This fact may account for the increased number of leaves. There was

significant increase in the number of leaves under first method. So, to explain this increase in number of leaves under the first method when treated with 10 ppm. indole acetic acid, it should be assumed that the number of leaves on the branches might have increased. However when two sprayings were given (third method of application) none of the concentrations of indole acetic acid could increase the number of leaves or the number of branches.

From an examination of the effective concentration of indole acetic acid in increasing the number of leaves it is seen that it varies with the method of application. It is seen also that none of the treatments with indole acetic acid under the third method of application could promote total number of leaves. It may be due to the fact that the internal level of auxins after two sprayings was not conducive to leaf formation. Although indole butyric acid was ineffective under the first method various concentrations were able to increase the number of leaves under the second and third methods. The gibberellic acid was totally effective neither to increase the number of leaves nor the number of branches. But under the second and third methods the number of leaves on the main shoot was increased on the 50th day.

The general behaviour of gibberellin in the various previous investigations, was not to increase the number of leaves. Of the many plants studied by Yabuta and Hayashi (1939) an increase in the number of leaves was only recorded in cucumber.

The leaf area was not affected by any of the treatments tried. The results reported so far vary in their effects. As far as gibberellic acid is concerned even slight inhibition of leaf expansion has been reported in tomato and cucurbits by Yabuta and Hayashi (1939).

Various concentrations of gibberellic acid, indole acetic acid and indole butyric acid have been able to increase the girth of plants significantly. No general agreement can be formulated for regulating the effective concentration of the hormones between different methods of application. With the use of gibberellic acid, Dransfield (1951) noticed increased girth in the lower internodes of cotton. Appala Naidu (1962) found a slight decrease in girth of plants in Hibiscus cannabinus var. purpurea and a slight increase in H.cannabinus var. vulgaris. Here also different concentrations of all hormones tried increased the girth to different degrees which is in conformity with the findings of some of the investigators referred above.

The ineffectiveness of the treatments to bring about any increase in height provides a basis for further investigation on the nature of cell elongation as affected by these treatments.

The fact that no effect on flowering noted under any of the hormone treatments tried confirms the view of Chakravarti and Abraham (1960) that gibberellic acid has no florigenic property.

While lower concentrations of gibberellic acid increased the fresh weight, under the second method, medium concentration was necessary to induce the response under the first method, which had only pre-sowing treatment. But in the third method, with no pre-sowing treatment higher concentrations were needed to induce this response, perhaps suggesting that the plant cells were more sensitive to gibberellic acid at the early period of growth.

Some concentrations of indole acetic acid and indole butyric acid also have increased the fresh weight of plants. But from the results obtained, no conclusion can be drawn about the specific effective concentration of the hormones used. It appears that this plant is highly sensitive to the nature of interaction between the applied and endogenous hormones and it

SUMMARY AND CONCLUSION

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The present work was undertaken to study the effects of gibberellic acid, indole acetic acid and indole butyric acid on the vegetable crop, amaranthus (Amaranthus gangeticus L). Three methods of treatment viz. seed treatment (soaking for 2 hours); seed treatment followed by one foliar spray on the 20th day, and two foliar sprays on 20th and 35th days were tried. All the hormones were used at concentrations of 10, 20 and 30 ppm. A pot culture experiment was conducted for the purpose, adopting a randomised block design.

The effect of hormones on the height of plant, number of leaves, leaf area, number of branches, total length of branches, girth of main stem at a particular internode, date of flowering and fresh weight of plants were studied. Of these, height of plants, total length of branches, leaf area and date of flowering were not at all influenced significantly by any of the treatments.

The number of leaves on the main stem on the 50th day was unaffected by the first method. In the second method, indole acetic acid did not give any in-

crease while under the third method of treatment higher concentrations of indole acetic acid were necessary to bring about any increase in number of leaves suggesting that the plants are more sensitive to hormones at seedling stage.

Total number of leaves at harvest was not affected by gibberellic acid treatment. Indole acetic acid at the first and second methods and indole butyric acid at the 2nd and 3rd methods gave significant increase at higher concentrations.

Number of branches was increased slightly by indole acetic acid at 20 ppm. concentration under the 2nd method, while indole butyric acid gave significant increase at 30 ppm. under the 3rd method.

Girth of plants was increased by lower concentrations of all hormones for the first method. Higher concentrations were necessary at the second and third methods of applications.

Regarding the fresh weight of plants, second method of treatment seemed to be the best. While lower concentrations of all hormones tried seemed to be enough for producing significant increase in the first

two methods, general trend is towards higher concentrations in the third method of treatment. But no regularity was noticed in the response of plants.

The non-response and irregularity of response of plants to hormones was tentatively attributed to two factors viz., varietal characteristics and interaction between the applied hormones and other growth factors at cellular level.

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FIGURE 11

General view of the experimental plot

FIG II

FIGURE 12

Comparison of plants treated with gibberellic acid under the first method (Seed treatment) with Control.

1. GA 10 ppm.
2. GA 20 ppm.
3. GA 30 ppm.
28. Control

FIGURE 13

Comparison of plants treated with Indole acetic acid under the first method (Seed treatment with Control)

4. IAA 10 ppm.
5. IAA 20 ppm.
6. IAA 30 ppm.
28. Control

FIG 12

FIG 13

FIGURE 14

Comparison of plants treated with indole butyric acid under the first method of treatment (Soaking seeds for 2 hours) with Control.

7. IBA 10 ppm.
8. IBA 20 ppm.
9. IBA 30 ppm.
28. Control

FIGURE 15

Comparison of plants treated with Gibberellic acid under the second method of treatment (Seed treatment followed by one foliar spray on the 20th day) with Control.

10. GA 10 ppm.
11. GA 20 ppm.
12. GA 30 ppm.
28. Control

Figure 14

Figure 15

FIGURE 16

Comparison of plants treated with indole acetic acid under the second method of treatment (Seed treatment followed by one foliar spray on the 20th day) with Control.

13. IAA 10 ppm.
14. IAA 20 ppm.
15. IAA 30 ppm.
28. Control.

FIGURE 17

Comparison of plants treated with indole butyric acid under the second method of treatment. (Seed treatment followed by one foliar spray on the 20th day) with Control.

16. IBA 10 ppm.
17. IBA 20 ppm.
18. IBA 30 ppm.
28. Control.

FIG 16

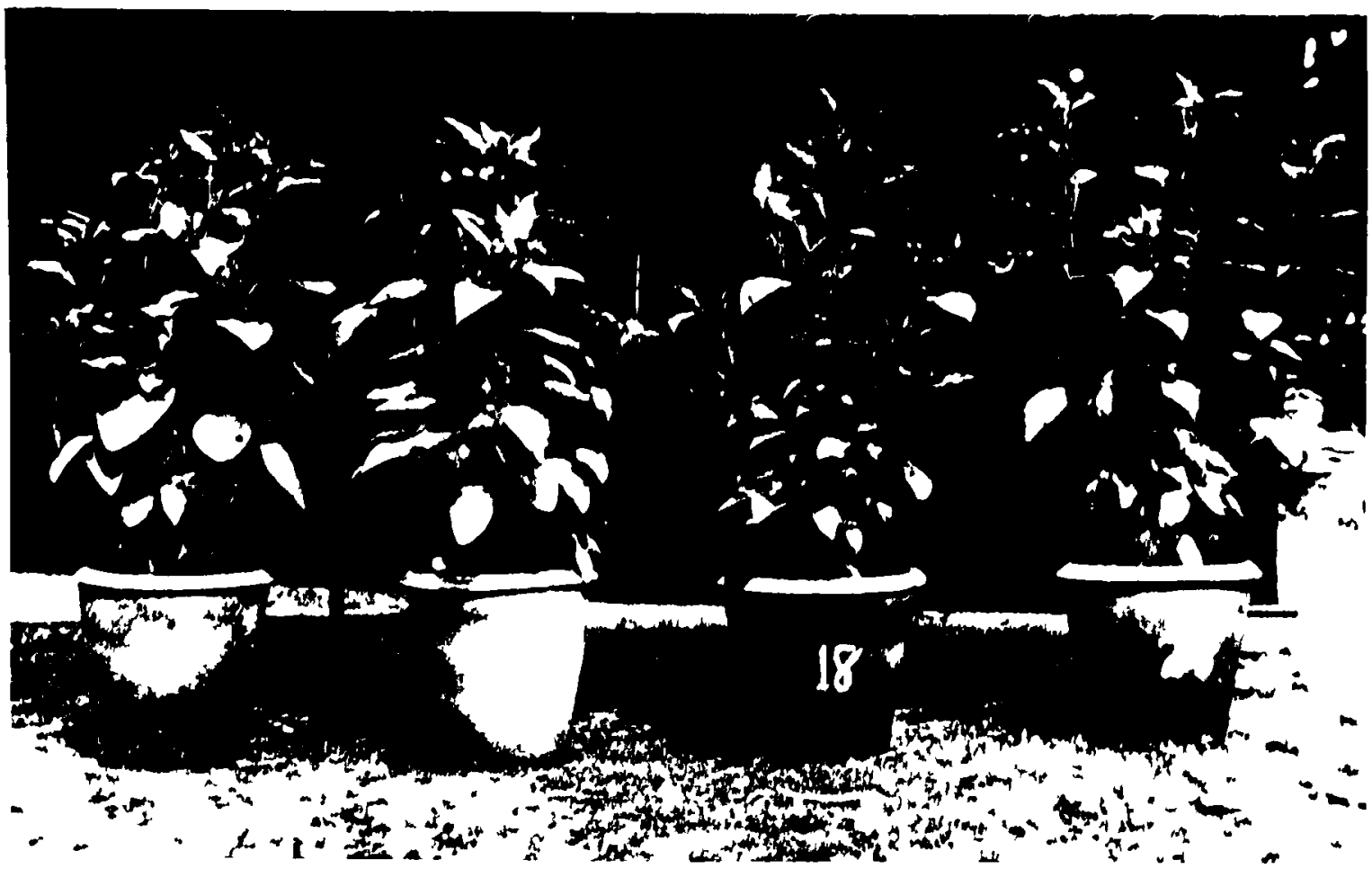

FIG 17

FIGURE 18

Comparison of plants treated with Gibberellic acid under the third method (Two foliar sprays) with Control.

19. GA 10 ppm.
20. GA 20 ppm.
21. GA 30 ppm.
28. Control.

FIGURE 19

Comparison of plants treated with indole acetic acid under the third method (Two foliar sprays) with Control.

22. IAA 10 ppm.
23. IAA 20 ppm.
24. IAA 30 ppm.
28. Control.

FIG 18

FIG 19

FIGURE 20

Comparison of plants treated with indole butyric acid under the third method (two foliar sprays) with Control plants.

25. IBA 10 ppm.
26. IBA 20 ppm.
27. IBA 30 ppm.
28. Control.

FIG 20