STUDIES ON THE EFFECT OF GROWTH REGULATORS ON GERMINATION, GROWTH AND OIL CONTENT IN SESAME (*Sesamum indicum*-L)

By

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THESIS

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CERTIFICATE

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Kumari S. Santhakumari 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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INTRODUCTION

INTRODUCTION

Sesamum indicum L. (Syn. S.orientale L.) known as sesame or gingelly belongs to the family pedaliaceae. It is an oil seed which furnishes one of the most important oils of domestic consumption in India. An area of about six million acres is now under sesame cultivation. The average production per acre is 185 lb. In respect of total world production, India stands next only to China, with a production of 26.14% (A.B. Joshi, 1961).

Considering the total world production of oil seeds sesame is placed next to other important oil yielding crops, soybean, ground nut, cotton-seed, linseed and rape-seed. But it plays a considerable part in the economy of the principal producing countries, as a rich and valuable source of edible vegetable fat. Besides, gingelly seeds are used directly as human food in Indian household. Sesame oil is used in medicine as a carrier for fat soluble substances. Sesame plant is considered valuable also as a medicinal herb. In India, the main oil seed crops in order of importance, are groundnut, rapeseed and mustard, sesame, linseed and castor, (A.B. Joshi, 1961).

Before the second world war India used to export some quantities of sesame, but after the war, these exports

become negligible. More recent figures show, ("Vegetable Oils and Oilseeds, London, 1958"), that in the year 1955 India exported three thousand tons of sesame seed and about four thousand tons of sesame oil. In the year 1956 there was again a sharp fall in exports. But now the internal consumption has increased much without corresponding increase in production, and the export has now practically ceased.

Research in India on this crop has been directed mainly towards introduction, hybridisation, selection, cultural and manurial requirements and control of pests and diseases. Recently trials with gibberellic acid have also been conducted in this crop.

Application of growth regulators in plant tissues, either by seed treatment or by spraying at different stages of growth has been found to have striking effect on growth, development, general vigour and final production of the plant, whether root, leaf, seed or fruit. Growth regulators applied to plants either on roots or on shoots are absorbed by the plants and when suitable concentrations are used they provoke characterestic growth responses of practical significance.

Extensive work has been carried out for studying the effect of growth regulators on crops like jowar, wheat,

paddy, cotton, sugarcane, tomato, tobacco, grapes, pea, cumin, linseed, safflower, lettuce etc., either by seed treatment or by spraying at different stages of the plant's growth. In many instances growth regulators have been found to be useful as general growth stimulants. Their application have also hastened and increased flower production and fruit-set leading to higher crop yields.

Investigations on the effect of gibberellic acid on Sesamum so far conducted were chiefly confined to the study of germination, flowering and morphological characters. But its effect on the total yield of the crop, fruit-set, seed-set and oil content has not been studied. Besides gibberellic acid, there are many other growth regulators which have also been found to be useful as general growth stimulants in other crops.

The present investigation has been undertaken to study the effect of gibberellic acid and two other growth regulators - naphthalene acetic acid (NAA) and 2, 4-dichlorophenoxy acetic acid (2, 4-D) on germination, growth and oil content of Sesamum indicum L.

REVIEW OF LITERATURE

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The field of plant growth regulators is now at the stage of rapid development. Within the last thirty years growth regulating substances came to be known in the agricultural and horticultural fields, in both scientific and popular literature alike. Originally the main emphasis regarding the research on growth regulators had been laid on a study of its biological and physiological role and its function as a chemical messenger. These fundamental studies finally led to botanical, agricultural and horticultural applications of growth regulators which have revealed that they can be put to varied uses for improving crop production. New methods for the control of plant growth and development through the use of growth regulators constitute one of the most spectacular agricultural applications in recent years. Flowering, fruit-set, fruit drop, dormancy, root formation and even the suppression of undesirable plants can all be controlled to advantage in certain crops through the use of plant growth regulators. Besides, plant growth regulators are useful in accelerating the germination of seeds, and even pollen grains in artificial media.

A great deal of work has been done on the above

lines in various crops, in different countries. But since much of these information is not directlyrelated to the present investigation, they are not discussed in this review. Only those which are directly related to the present investigation are dealt with.

Seed treatment:

Numerous reports had been published concerning the treatment of seeds of many plants with growth regulators. These treatments varied from harmful, no effect to beneficial effects. Beneficial effects of synthetic growth substances on seed germination were first investigated by Cholodny (1936), Grace (1937, 1941), Stier and DuBuy (1939), Tang and Lou (1940), Mc Elroy (1942) and Thimann and Lane (1946).

Hsueh and Lou (1947) obtained stimulation of seed germination by 0.01% solution of 2, 4-D, but o.o7% solution completely inhibited barley germination and delayed germination of rice. Randhawa and Hamner (1949) reported that germination of bean seeds soaked in growth regulators were greatly delayed, but when soaked in a mixture of antibiotics and growth regulator, germination was considerably improved. Kumara Pillai (1963) observed that when seeds of bittergourd representing hard coated seeds and green grams representing soft coated seeds were soaked for 24 hours be-

fore sowing in 0.02% I A A, I B A and N A A, the germination of both hard and soft coated seeds were inhibited.

Narasimha Rao et al., (1957) by pre-soaking in different concentrations of indole acetic acid and naphthalene acetic acid found that germination percentage of ground-nut kernals variety T.M.V.1 could be increased by 86.0 to 94.4%. The yields of pods could also be improved by the use of these growth regulating chemicals, though flowering maturity period and oil content remained unaffected. Chatterjee (1960) in Aleurites fordii obtained increased percentage of germination and healthy seedlings by pre-sowing treatment with I A A, I B A, N A A, I P A and P A A at 50 and 500 ppm. but 2, 4-D and T C P reduced them especially at 500 ppm. concentration. Narayanan and Vasudeva Menon (1960) obtained favourable results by pre-soaking the seeds of paddy and ragi in N A A and I A A. But the influence of pre-soaking treatments on the growth of rice plants varied at Coimbatore and Adathurai. In the case of ragi I A A trated plants were taller in the early stages and increased the number of tillers and leaves. In the case of N A A no difference in plant height has been observed. But both the treatments improved the yield of ragi. Gandhi and Bhatnagar (1961) reported the effect of N A A, I A A and

I P A at three concentrations viz. 10 ppm., 50 ppm. and 100 ppm. on germination, flowering, fruiting, branching and yield of Cuminum cyminum. Germination of cumin seed has been enhanced at the concentration of 10 ppm. of the hormones and the total yield was increased by all the concentrations.

Since the discovery of gibberellic acid many workers have studied its effect on germination of various seeds. Helgeson and Green (1957) could promote the germination percentage of wild oats with gibberellic acid. Kahn, Goss and Smith (1957) studied the effect of gibberellic acid on the germination of lettuce seeds and proved that gibberellin can substitute the red light treatment required to break dormancy with seeds of lettuce. This effect was not reversed by exposure to far-red light sufficient to reverse the red light effect. Tool and Cathey (1959) found that a solution of gibberellin in water caused light requiring seeds of lettuce to germinate in total darkness. De Leon and Derafols (1959) observed in Kok-saghys seeds and broad bean seeds that G A at 5 ppm. greatly accelerated germination, but the effect was progressively less marked when the concentration was increased. Mc Vey and Wittwer (1959) obtained increased rate and percentage of germination in

blue grass by soaking the seeds in 100 or 1000 ppm. G A solution. Pisani (1959) observed that the application of 10 ppm. gibberellin in water solution to the seeds of lettuce, spinach, eggplant, radish, marrow, bean, carrot and onion had favourable effects on the speed and amount of germination. Skinner, Talbert and Shive (1959) obtained 11 and 15% increased percentage of germination in lettuce by soaking the seeds in a gibberellic acid solution of concentration 30 and 100 mg./L. Ikuma and Thimann (1960) observed that shaking the seeds of lettuce with a G A solution at 60 ppm. throughout the period of imbibition and germination induces maximum germination. Zujagina (1961) found that the germination of freshly harvested seeds from 7 species of Nicotiana and from a hybrid of Nicotiana sp. X N.Tabaccum was greatly improved by placing them in petri dishes moistened with 0.02% G A.

Gray (1956) observed that seedlings of cherry from seed treated with gibberellic acid-methyl cellulose came up faster and grew taller than seedlings from untreated seeds. Baker and John (1958) studied the action of gibberellic acid, 2, 4-D and I A A on seed germination and epicotyl and radicle elongation of intermediate and pubescent wheat grass. They observed that none of the chemicals

increased radicle elongation over the control. But at 200 ppm. of G A radicle elongation was greatly increased in Agropyron intermedium while in Agropyron trichophorus the response to G A was not very marked. Moore (1958) observed that when the seeds of pea are saturated with G A solution of 1.0 mgm./L the main axis of the stems exhibited markedly increased elongation. But the stems of treated seedlings were markedly thin compared with the control. Tod (1958) obtained increased percentage of germination of Anemone cotoneaster and Primula seeds, by soaking for 20 hours in gibberellic acid solution, but in no case was any stimulation of growth visible in the seedlings grown from treated seeds. Pieri (1959) observed that the treatment of vine seeds by 10 days immersion in 10, 25, 50 or 100 ppm. of G A induced seedlings to grow faster than the controls for about a month. But before the end of growing season, they were overtaken by the control. Herich (1960) observed that when seeds of Cannabis sativa were soaked for 24 hours in solutions containing 5, 10, 25 and 100 ppm. of G A an increased percentage of female plants were obtained, the highest increase being caused by 10 ppm. concentration. Vinodhini Vasudevan and Moosa Sheriff (1963) studied the effect of gibberellic acid on the germination and initial growth of paddy seeds. Paddy seeds of variety TKM.6 were germinated

in petri dishes on filter paper moistened with solutions of 5, 10, 20, 40, 80, 160, 200 and 400 ppm. G A in laboratory conditions. Gibberellic acid treatment of paddy seed decreased germination. The final germination percentage was not affected by any concentration of gibberellic acid with the exception of 80 and 40 ppm. concentrations which almost completely inhibited germination. But regarding the initial growth, the pre-soaking of paddy seeds in the various concentrations of gibberellic acid significantly proved superior to seedlings grown from water soaked and unsoaked seeds with regard to increase in the initial shoot height which increased with increasing concentrations of gibberellic acid.

Chakravarthi (1958) observed that seed treatments of Brassica campestris, Cicer arietinum and Lens esculenta with G A failed to produce earliness in flowering. Application of gibberellic acid to growing plants however was effective in inducing earliness in Brassica. Mazzani and Gonzales (1959) reported the effect of G A on sesame, bean, tomato and papaw. Germination of sesame, bean, tomato and papaw seeds was unaltered by seed treatment with gibberellin, but seedling growth was accelerated and seedling heights were roughly proportional to the concentration of gibberellin which caused elongation of the internodes, but

repeated treatments had cumulative effects and very high concentrations were phytotoxic.

Choudhury and Singh (1960) studied the effect of seed treatment with plant growth regulators such as NOA (25, 50, 100 and 150 ppm.) CIPA (10, 20, 30 and 40 ppm.), 2, 4-D (0.5, 1, 2 and 2.5 ppm.) and G A (5, 10, 15 and 20 ppm.), for 24 hours on the growth and yield of Lycopersicum esculentum. Observations revealed that when tomato seeds soaked with proper concentrations resulted in better germination, quicker growth and higher yield of fruits. But the higher concentrations of 2, 4-D (2 and 2.5 ppm.) and C I P A (30 and 40 ppm.) resulted in some what adverse effect on growth and yield of tomato plants. NOA at 25 and 50 ppm. G A at all concentrations (5, 10, 15 and 20 ppm.) and CIPA at 10 and 20 ppm. gave significantly higher growth of the main stem and yield of the fruit than the control. 2, 4-D at 1 and 2 ppm. though gave better growth, did not give higher yield of fruit.

Spray applications:

Effect on morphological characters such as leaf abnormalities, height, branching, total number of nodes and fresh weight and dry weight of plants:

Studies with the growth regulators have revealed

that they have a profound effect on the morphological characters of plants.

Murneek, Wittwer and Hemphill (1944) reported the effect of spray applications of growth regulators on snap-beans. By spraying naphthalene acetamide and naphthoxy acetic acid at concentrations ranging from 5-25 ppm. the volume and yield of the crop was increased considerably. Krishnamurthy and Beeranna Bhandari (1957) obtained modifications in the leaves of Chilli (Capsicum frutescens) by spraying the whole plant with high concentrations of beta-naphthoxy acetic acid and 2, 4-D. Singh (1957) recorded that in tomato and Coleus seedlings spray application with 1000 ppm. naphthoxy acetic acid showed increased growth.

Kiermayer (1959) found that application of N A A at higher concentration in tomato produced morphological effects such as abnormal flower formation, the formation of lateral shoots and morphological changes in the leaves. But N A A in combination with T I B A prevented these morphological changes.

Brian et al.,(1955, 1958) reviewed the effect of gibberellic acid on various plants in full. Marth Audia and Mitchell (1956) reported the effect of gibberellic acid on growth and development of plants of various genera and species. In general, treated plants developed temporarily

paler leaves either narrower or broader than the normal. De Leon and Derafols (1959) observed that in Kok-saghys and broad-bean plants spray application of G A at 5 ppm. resulted in increased number and size of leaves.

Chakravarthi (1958) reported the effect of G A at concentrations 1, 10 and 100 ppm. on 10 days seedlings of Sesamum indicum. Most treatments resulted in elongation of internodes, the degree of which was directly proportional to the concentration. The high concentration of G A changed the shape of leaves. Bonde and Moore (1959) found that single sprays of increasing concentrations of G A in the range of 0.0015 to 15.0 mg./L had increasing stimulating effect on the stem elongation of dwarf telephone peas. Increasing concentration of G A increased the number of nodes and flowers, but the time of flowering was not affected. Doljakoff - Mayber and Mayer (1959) observed that in lettuce prolonged application of G A affects the internodes resulting in elongation and causes earlier flower formation. But single application or seed treatment is ineffective. Yoda and Ashida (1959) reported the effect of gibberellin on the extensibility of pea stem, extensibility being effected in the internodel cells, but I A A had opposite effect. Wellensiek (1960) observed that in long day conditions a considerable stem elongation of Maryland Mammoth

tobacco could be obtained by G A treatment of 100 ppm. concentration. After transfer to short day conditions one control plant formed flower buds after 54 days, were as two plants treated with G A did not do so until after 71 days. Hence stem elongation would appear to have retarded flower bud initiation. Lawrence Rappaport and Singh (1961) observed in vegetable crops that the most recognizable effect of gibberellin is stem elongation. Steyens, Roberts and Williams (1961) found that in hops (Humulus lupulus L.) spray application of G A at 12.5 ppm. resulted in paler green leaves, extension of internodes in laterals, G A sprays at cotyledon stage at concentration of 1, 5 and 10 ppm. resulted in considerable elongation of the seedlings.

Brian and Hemming (1956) obtained increased growth rate, height and weight of dwarf varieties of pea by application of 0.01 mg. of G A per plant to the leaves at seedling stage. Bukovac and Wittwer (1956) made a detailed study of general growth responses of gibberellic acid on higher plants. They again in 1957 studied the general effect of gibberellin on the growth habit of many crop plants. Treatment with gibberellin had produced significant increase in both fresh weight and dry matter in celery, and has hastened flowering and maturity in beans.

Moscolov and Moscolova (1959) studied the effect of gibberellin on the growth and development of agricultural crops, lettuce, celeriac, parsley, onion and garlic.G A sprayed at 50 and 100 mg./L increased the uptake and assimilation of nutrients with consequent increases in their fresh and dry weight. Thorup (1959) observed that treatment of young plants with G A stimulated cell elongation in stems, shoots and petioles, increased fresh weight, advanced flowering and favoured fruit-set. In a Coleus variety, spraying with 25-100 ppm. G A produced the maximum number of lateral shoots of the first order. In Coprosoma sp. drop treatments of lateral shoots resulted in compact growth. Gonzalez and Gjerstad (1960) observed morphologic and metabolic changes induced by G A on spearmint, by an increase in dry matter content and decrease in volatile oil content. Kryskov and Skurat (1961) studied that G A application at 0.0001% and 0.01% to peppermint resulted in better growth but had less dense foliage and lower essential oil content. Ogzewalla (1961) observed that spray application of G A at 10 and 100 ppm. reduced fresh weight, dry weight and oil yield of Peppermint.

Singh, Randhawa and Jain (1960) studied in detail the responses to the application of G A in strawberry.

They found that G A sprays increased the height and spread of plants, number and length of runners, hastened flower formation and fruit maturity and increased the total yield and quality of fruits. Appalanaidu and Satyanarayana Murthy (1962) studied the effect of gibberellic acid on growth and yield of four varieties of Mesta under pot culture conditions by spraying aqueous solutions of G A at 0, 1, 5, 25, 50 and 100 ppm. for four times at weekly intervals. Growth of manchigogu and red pusa gogu is stimulated markedly while kondagogu and white Pusagogu have not responded. The increase in shoot extension is mostly due to increase in internodal elongation and not due to production of more internodes. The differential behaviour of 4 varieties seem to depend on succulence of the shoot rather than the tallness or dwarfness of the variety, the stimulation in shoot extension is associated with malformation of leaf and reduction in leaf size. Production of more branches, less fruits, and delayed flowering occurred with the rise in concentration of G A in the varieties that have responded.

Zanardi (1956) observed that spray application of 2, 4-D at 6 ppm. to capsicum plants resulted in dwarfed and deformed leaves, abortion of flower buds and malformation of fruits. Appalanaidu (1959) studied the morphological and histological effects of sprays and injection of 2, 4-D

at concentrations ranging from 100-5000 ppm. on Brassica and Okra. In Brassica even the lowest concentration proved to be lethal. Okra responded rapdily, the floral organs becoming abnormal and roots developing from internal stem tissues. In both, leaf and petioles became twisted and the blades epinastic. The growth of the axillary buds was inhibited by injecting 2, 4-D into decapitated stem.

Effect on flowering:

Evidence is being accumulated that the growth regulators could be employed to control and accelerate flowering in many crop plants.

Clark and Kerns as early as 1942, Cooper (1942) (cited by Skoog) and subsequently Van Overbeek (1946) reported that flowering in pine apple can be induced with certain synthetic growth regulators, such as 50 millilitres of N A A or 2, 4-D at a concentration of 5 ppm. Leopald and Thimann (1949) were able to increase by as much as 35% the number of flowers in barley by applying a weak solution of N A A, through the cut surface of leaves.

Gibberellic acid also behaves similarly to N A A in its effect on flowering. Chakravarthi and Abraham

(1959) studied the effect of G A on the flowering of Sesamum indicum. Applications of aqueous solutions of G A in concentrations of 1, 10 and 100 ppm. as a pre-soak treatment of seeds, as foliar sprays, and as drops for different durations at 3 stages of life cycle of Sesamum indicum were made. Flower induction was not hastened by any of these treatments. However induction was significantly delayed when plants 10 and 24 days old received a repeated treatment with 100 ppm. of G A. Thorup (1959) found that treatment of G A advanced flowering in Cleome monophylla, Tagetes patula and Pelargonium zonale and favoured fruit-set in Ricinus communis. Itakura, Shiraki,Y and Shiraki, S.(1959) reported that vegetative growth was stimulated and flowering was accelerated in horticultural plants like petunia, pansy, cyclamon, hydrangia, narcissus, Primula malacoides, and Adonis amurensis by spray application of G A at 25, 50 and 100 ppm.

Effect on fruit-set, seed-set and oil content:

Growth regulators had been found to be useful in supplementing or substituting normal pollination in the setting of fruits.

Luckwill (1953) reported that naphthalene acetic

acid is useful in effecting fruit-set in apples. Grane and Bradley (1956) observed that in stewart apricots aqueous sprays containing 100 ppm. of N A A, 2, 4-D and 2, 4, 5-T, hastened fruit maturity by about one week, increased the fruit size and controlled pre-harvest drop of fruits. Ueno (1956) working in straberries observed that N A A applied at higher concentration before flower formation inhibited flowering and fruiting considerably but was not so effective, when applied after flower formation. Kepkowa (1959) found that application of beta-naphthoxy acetic acid and alpha-naphthalene acetic acid in tomato increased considerably, the early yields and percentage of small fruit was considerably, reduced, but the spray had only slight favourable effect on the total yield of tomatoes. Randhawa, Sharma and Jain (1961) studied the effect of N A A (25, 50 and 75 ppm.) 2, 4-D (5, 10 and 15 ppm.) and 2, 4, 5-T (10, 20 and 30 ppm.), when sprayed after fruit-set with a view to evaluating their effect on fruit-drop size and quality of three sweet orange varieties (Jaffa, pineapple and mosambi). Treatments with 2, 4-D at 10 and 15 ppm. and 2, 4, 5-T at 30 ppm. in general improved the average weight of fruits. Fruit drop was also reduced to a considerable extent by the treatments.

Takashima, Izuta and Kitao (1957) obtained a considerable increase in seed production in cucurbits and tomato, resulting from spraying the stigmas with N A A at flowering time immediately before pollination. Marsh, Southwick and Weeks (1961) found that sprays of N A A and Na- acetamide after petal fall can reduce fruit-set in apples without any significant effect on the number of viable or aborted seeds in either the dropping or persisting fruits.

Wittwer and Bukovac et al., (1957) reported the effect of gibberellic acid on crop production. They observed that treatment with gibberellin has hastened flowering and maturity in beans and tomato. Gibberallin also proved to be very effective in the setting of tomato fruits. Rappaport (1957) observed that in tomato, simple or repeated application of 25, 50 and 100 mg. of gibberellin hastened flowering by 3-10 days without affecting node number up to first inflorescence. Setting of normal and parthenocarpic fruit was increased by repeated floral sprays. Krimbas, Davidas and Michailidis (1959) found that spray application of G A at 10, 20, or 30 ppm. to black corinth grapes 3 days after full bloom increased fruit size and approximately doubled the yield of fresh fruits as compared

with control vines, but the sultania vines sprayed with 20, 30 or 50 ppm. G A solution gave no clear positive response but the raisins produced from their fruit were tougher and darker. Krishnamurthi, Randhawa and Singh (1959) observed that in Pusa seedless variety of grapes (Vitis vinifera L.) G A at concentrations of 10 and 25 ppm. sprayed to the flower clusters increased fruit-set by 76.5% and 59.1% respectively, and at 50 ppm. reduced fruit-set by 15.41%. Randhawa, Singh and Khana (1959) obtained increased fruit-set in phalsa by spray application of 10 ppm. G A. Randhawa, Singh and Dhuria (1959) working with sweet lime found that G A at 10 ppm. and 2, 4-D at 10 and 15 ppm. increased fruit-set considerably and reduced fruit-drop. Bukovac, Larsoen and Bell (1960) found that in concord grapes fresh and dry weight and number of berries per cluster were not significantly affected by G A sprays of 10, 25 and 100 ppm. Gustafson (1960) in tomato observed that 35 and 70 ppm. G A sprays on flower clusters enhanced setting, but the total weight of fruits was lower. Lawrence Rappaport and Singh (1961) observed that in tomato flower sprays containing 1-500 mg./L. G A resulted in parthenocarpic fruit-set, early fruiting and increased yield.

Bukovac and Wittwer (1956) found that gibberellin accelerated flowering and seed production in several

varieties of lettuce, mustard and radish and improved setting of fruits in tomatoes. Seed production in several varieties of mustard and radish was accompanied by marked elongation of seed stalks. Muromcev and others (1960) reported that G A application to seedlings and inflorescences of mature tomato plant accelerated ripening of fruit and increased yield by 23-66%. Seedlings of carrot, turnip and radish sprayed with G A also produced flower stalks and flowers in their first year although no seeds were set.

Singh and Randhawa (1959) studied the effect of G A and C I P A (Parachlorophenoxy acetic acid) on growth and fruit fulness in strawberry. G A at 5 and 10 ppm. increased the height of plant, length of peduncle and fruit and total yield per plant by 46 and 62% respectively. G A was much more effective in increasing total yield than C I P A, although it increased the early fruit maturity. Yermanos and Knowles (1960) studied the effect of G A treatment on safflower. Application of G A at 10 and 100 ppm. before flowering induced rapid internode elongation and chlorosis. Abnormalities in the development of inflorescence resulted in various degrees of sterility. In treated plants maturity was hastened. Yield and oil content was depressed, but seed weight and iodine number was not affected.

Stewart and Parker (1954) reported that in grapes 2, 4-D is effective for increasing yield, size and quality of grape fruit. Krishnamurthy and Subramoniyan (1954) in brinjal (Solanum melangona) found that application of 2, 4-D as a paste at 0.0025-0.01% or as water sprays at 0.0005% increased fruit-set as a whole by 50-60%. Taguchi and Nishiri (1955) observed that concentrations of 0.0007, 0.0005% of 2, 4-D have proved useful in improving the seed set of varietal crosses, in potato varieties, that are otherwise difficult to effect. Krjackov (1956) found that at 2037 m. above sea level 0.001% 2, 4-D sprayed on tomato varieties six times during flowering advanced ripening and increased both fruit size and yield. Muthukrishnan (1957) found that an application of 2, 4-D at 5 ppm. as water spray to the flowers of brinjal resulted in an increased fruit-set of 25% more than the control and reduced the blossom drop to 66.4%.

Abdul Ravoof (1963) studied the effect of N A A, 2, 4-D, G A and boric acid on fruit-set, maturity and composition in sapota fruits. He observed that N A A, 2, 4-D and boric acid increased the fruit-set, while G A and N A A failed to show any response. Half mature fruit of the varieties baramasi and kritabarti were treated with N A A, 2-4D, and G A at concentrations of 100, 150 and 200

ppm., 25,75 and 125 ppm. and 100, 200 and 400 ppm. respectively. Maturity was hastened by 46 days in baramasi, with 25 ppm. of 2, 4-D. The lower concentrations appeared to be more desirable. However reductions in the size and weight of fruits were associated with the treatments and the result varied even within the same concentrations. The number and weight of seeds were not influenced by the different treatments. Regardless of the concentrations of growth regulators used, the percentage of total soluble solids, total sugars and reducing sugars decreased as compared with the untreated control. The acid content, however did not show any constant effect. Srinivasan, Meenakshi and Jambulingam (1963) studied the effect of phyto hormones on pod set in Dolichos lab-lab var. typicus. The growth regulators G A, N A A and I B A were applied as aqueous sprays at 10 ppm. and 50 ppm., respectively at two stages of flowering. In the case of G A 10 ppm. a second treatment was also given. Increase on the percentage of pod-set was observed among the treated racemes. The G A foliar-cum-inflorescence spray gave the maximum pod-set of 34.6%, while the untreated control registered 24.4%.

The effect on the oil content and iodine number of the oil content in flax has been investigated by

Tandon (1949), Klosterman and Clagett (1948) and Paatela (1949) (cited by R.S.Dunham, 1951). Tandon (1949) found that oil percentage and iodine number were reduced by amine and sodium salts of 2, 4-D applied at 4, 8 and 16 oz. per acre. Paatela (1949) reported a reduction in oil upto 2.3% when flax was sprayed with morpholine salt of 2, 4-D in the bud stage and a reduction in the iodine number, when treated in the cotyledon stage. Klosterman and Clagett (1948) sprayed 0.175 pounds of 2, 4-D per acre in the form of alkano amine salt. No significant differences were found in oil percentage while the iodine number was significantly increased. Largest reductions in oil percentage resulted from spraying in prebud and late bud stages, the first stages representing the approximate end of vegetative growth.

MATERIALS AND METHODS

MATERIALS AND METHODS

The investigations reported here were carried out in the year 1962-63 at the Agricultural College and Research Institute, Vellayani. An early maturing variety of three months duration (local variety of Vellayani) provided the experimental material for the present studies.

Since sufficient attention is not paid to seed material of sesamum in Vellayani, seeds were obtained from 5 different sources and it was found that the percentage of germination among the different lots was highly variable. The seed lot which gave the highest germination percentage was selected for the present studies.

The following growth regulators were used for the studies:

(1) Naphthalene acetic acid (NAA) supplied by Eastman, Organic Chemicals, Rochester, U.S.A.

(2) Gibberellic acid (GA) supplied by B.D.H. Bombay.

(3) 2, 4-dichlorophenoxy acetic acid (2, 4-D) supplied by B.D.H. (horticultural quality), Bombay.

Preliminary studies were conducted to fix the different concentrations of the chemicals. These growth

regulators at varying concentrations were sprayed on a crop raised from the above seed. NAA at a concentration of 50 ppm. and above caused abnormalities and 100 ppm. proved to be lethal. Gibberellic acid at 100 ppm. and 2, 4-D at 10 ppm. also caused abnormalities in the growth of the plant. Hence the different concentrations of the growth regulators used for the experiment were fixed as follows:-

(1) NAA

i - 0
ii - 15 ppm.
iii - 30 ppm.

(2) GA

i - 0
ii - 25 ppm.
iii - 50 ppm.

(3) 2, 4-D

i - 0
ii - 2 ppm.
iii - 5 ppm.

The solutions were prepared by first dissolving the required quantity of chemical in 2 cc. of 95% alcohol and then diluting by adding water to obtain the

required concentrations.

Applications of the above growth regulating substances were made at three different stages, in the life cycle of the plant.

(1) Seed. (Seed treatment)

(2) Seedling. ('Seedling spray') Treatment was given when the seedlings were 20 days old.

(3) At the time of flowering 'flower spray'. The time of flowering had been fixed as the time, when all the plants receiving treatment had produced at least two flowers.

Statistical layout of the experiment

Lay out - Randomised block design

Replication - 5

Treatments - 27

1. NAA 0 level seed treatment
2. NAA 0 level 'seedling spray'
3. NAA 0 level 'flower spray'
4. NAA 15 ppm. seed treatment
5. NAA 15 ppm. 'seedling spray'
6. NAA 15 ppm. 'flower spray'

7. NAA 30 ppm. seed treatment
8. NAA 30 ppm. 'seedling spray'
9. NAA 30 ppm. 'flower spray'
10. GA 0 level seed treatment
11. GA 0 level 'seedling spray'
12. GA 0 level 'flower spray'
13. GA 25 ppm. seed treatment
14. GA 25 ppm. 'seedling spray'
15. GA 25 ppm. 'flower spray'
16. GA 50 ppm. seed treatment
17. GA 50 ppm. 'seedling spray'
18. GA 50 ppm. 'flower spray'
19. 2, 4-D 0 level seed treatment
20. 2, 4-D 0 level 'seedling spray'
21. 2, 4-D 0 level 'flower spray'
22. 2, 4-D 2 ppm. seed treatment
23. 2, 4-D 2 ppm. 'seedling spray'
24. 2, 4-D 2 ppm. 'flower spray'
25. 2, 4-D 5 ppm. seed treatment
26. 2, 4-D 5 ppm. 'seedling spray'
27. 2, 4-D 5 ppm. 'flower spray'

Preparation of the Experimental pots:

One hundred and thirty five earthern pots of 12" diameter were selected for the purpose. Pots were fil-

led with equal amounts of 1:1:1 mixture of sand, red earth and cowdung.

Treatments

1. Seed treatment:

The seeds receiving treatments were soaked in the growth regulators for 12 hours before sowing.

Treatments		Tt. No.
NAA	0 level	1
NAA	15 ppm.	4
NAA	30 ppm.	7
GA	0 level	10
GA	25 ppm.	13
GA	50 ppm.	16
2, 4-D	0 level	19
2, 4-D	2 ppm.	22
2, 4-D	5 ppm.	25

Sowing:

Seeds were sown on 29-11-1962. In each pot four holes were taken and 10 seeds per hole were sown at a depth of ½". After eight days thinning was carried out retaining only four plants in a pot with a spacing of 4".

Spray treatments:

Spraying was carried out with an atomiser until a thorough wetting of the plant was accomplished.

2. 'Seedling spray':

Seedlings were sprayed on the 20th day after sowing.

Treatments		Tt. No.
NAA	0 level	2
NAA	15 ppm.	5
NAA	30 ppm.	8
GA	0 level	11
GA	25 ppm.	14
GA	50 ppm.	17
2, 4-D	0 level	20
2, 4-D	2 ppm.	23
2, 4-D	5 ppm.	26

3. 'Flower spray':

The treatment was given on the 44th day after sowing.

Treatment		Tt. No.
NAA	0 level	3
NAA	15 ppm.	6

NAA	30 ppm.	9
GA	0 level	12
GA	25 ppm.	15
GA	50 ppm.	18
2, 4-D	0 level	21
2, 4-D	2 ppm.	24
2, 4-D	5 ppm.	27

Observations recorded

The following aspects were studied:

1. Germination percentage
2. Height of plants
3. Number of branches
4. Total number of nodes
5. Fresh weight of stem
6. Number of flowers
7. Number of fruits
8. Percentage of fruit set
9. Yield of seeds
10. Oil content

1. Germination percentage:

The germination percentage was studied separately, under laboratory conditions with 7 treatments re-

plicated 4 times. The seeds were kept for germination in petri-dishes with filter paper, moistened at regular intervals with equal quantities of distilled water. Every possible care was taken to keep the filter paper moist during the course of the experiment.

Treatments:

1. Control - soaked in distilled water
2. NAA 15 ppm.
3. NAA 30 ppm.
4. GA 25 ppm.
5. GA 50 ppm.
6. 2, 4-D 2 ppm.
7. 2, 4-D 5 ppm.

The germinated seeds were removed and counted at 12 hour intervals for 11 days after which no seeds germinated. The observations were analysed statistically.

2. Height of plants:

Height of plants was recorded by measuring the height of main stem, one week after sowing at 7 day intervals till the time of harvest and the final height of the plants were analysed statistically.

3. Number of branches:

The number of branches produced was counted at the time of harvest and the results were statistically analysed.

4. Number of nodes:

At the time of harvest the number of nodes in branches and main stem was counted and the data were subjected to statistical analysis.

5. Fresh weight of stems:

Due to abscission of older leaves it was not possible to determine the fresh weight of the plant. Therefore the fresh weight of the stem alone without leaves, flowers and fruits was recorded after harvest and statistically analysed.

6. Number of flowers:

Opened flowers were counted daily in the morning from 4-1-1963 to 13-2-1963, when flower production almost ceased completely. The total number of flowers produced were statistically analysed.

7. Number of fruits:

The total number of fruits set, in each plant, was counted and the data were subjected to statistical analysis.

8. Percentage of fruit-set:

From the number of flowers produced and the number of fruits set the percentage of fruit-set was calculated and was analysed statistically.

9. Yield of seeds:

The seeds from plants of each pot were collected separately, sun-dried, weighed and the data were subjected to statistical analysis.

10. Oil content:

"Cold percolation method" for rapid gravimetric estimation of oil seeds developed by Kartha and Sethi (1955) was adopted, for estimating the oil content, in the present study. The experimental procedure is detailed below:

0.2 gms. of seed was accurately weighed by a chemical balance and transferred to a glass mortar. 2.0 gms.

each of glass powder (Pyrex glass powder washed with hydrochloric acid) and anhydrous sodium sulphate (Na_2SO_4) were added and the mixture reduced to fine powder. The mixture was transferred to a small glass percolator, 20 cms. long and 1.5 cms. in diameter, and packed over a 0.3" thick layer of coarsely powdered anhydrous sodium sulphate. Filter bed of sodium sulphate was supported on a thin wad of cotton-wool placed over the perforated glass plate kept within the glass percolator. The mortar and pestle were washed twice with 0.5 gms. of anhydrous sodium sulphate and the washings were also packed over the mixture of seed powder. Finally the mortar and pestle were washed with 3-4 cc. of carbon tetrachloride (boiling point 70-90°C) and this was transferred to the packed meal powder. This initial 3-4 cc. of the solvent served to wet the mass. This was allowed to remain as such for 5 minutes and then percolation started by adding 20 cc. of the solvent on the top of the meal column. The solvent was collected in a weighed dish containing 4-one inch square strips of filter paper and was evoparated by keeping the dish in an oven at 98-105°C for half an hour. The weight of the dish was again determined. The difference in weight gave the weight of the oil in 0.2 gms. of seed.

The oil content of the samples from 18 treatments and one control were determined by the above method. The estimation was repeated with another set of samples and the mean was taken.

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

The effect of the three growth regulators, NAA, GA and 2, 4-D on Sesamum indicum was studied by observing the germination percentage, height of plants, number of branches, total number of nodes, fresh weight of stem, number of flowers, number of fruits, percentage of fruit-set, yield of seeds and percentage of oil content. The data so obtained were statistically analysed.

TABLE I

Analysis of variance table

Germination percentage transformed to degrees

Source	S.S.	d.f.	Var.	F
Total	297.85	27		
Block	4.49	3	1.50	0.31
Treatment	207.53	6	34.59	7.25**
Error	85.87	18	4.77	

**Significant at 1% level

TABLE II

Average germination percentage

Rank	Treatment number	Details of treatment	Average germination percentage	Difference from control
1	7	2, 4-D 5 ppm.	66.50	10.50
2	6	2, 4-D 2 ppm.	63.50	7.50
3	2	NAA 15 ppm.	62.50	6.50
4	5	GA 50 ppm.	60.75	4.75
5	4	GA 25 ppm.	60.00	4.00
6	1	Control	56.00	
7	3	NAA 30 ppm.	51.25	- 4.75

Critical difference = .559

7 6 2 5 4 1 3

GERMINATION PERCENTAGE

The germination percentage was transformed to degrees by the Sin^{-1} transformation and the data were analysed statistically. The analysis of variance table is given in Table No.I. The treatments are found to be significant indicating that germination was affected by the growth regulators. The average germination corresponding to different treatments is given in Table No.II.

Treatments with 2, 4-D gave the highest percentage of germination. Comparing two levels of 2, 4-D it is found that the effect of 5 ppm. is significantly superior to that of 2 ppm. Treatments with 15 ppm. NAA, though inferior to 2, 4-D is superior to GA 50 ppm., GA 25 ppm., control and NAA 30 ppm., the differences being significant. Of the two levels of GA, 50 ppm. gave better results than 25 ppm., which itself was superior to the control, the differences being significant. It was found that 30 ppm. NAA significantly reduced germination, when compared with the control. The highest percentage of germination was noted with treatment No.7 followed by others in the order 7 6 2 5 4 1 3.

TABLE III

Analysis of variance table

Height of plants

Source	S.S.	d.f.	Var.	F.
Total	92126.10	134		
Block	381.01	4	95.25	0.26
Treatment	51764.20	18	2875.78	8.01**
NAA, GA, 2, 4-D and Control	36363.20	3	1212.06	33.95**
Levels of NAA and Control	12808.30	2	6404.15	17.93**
Levels of GA and Control	5914.42	2	2957.21	8.28**
Levels of 2, 4-D and Control	30814.98	2	15407.49	43.16**
Stages of applications and Control	34754.60	3	11584.86	32.45**
Stages of applications of NAA and Control	13644.70	2	6822.35	19.16**
Stages of applications of GA and Control	20799.40	2	10399.70	29.13**
Stages of applications of 2, 4-D and Control	30994.95	2	15497.48	43.41**
Error	39981.10	112	356.97	

**Significant at 1% level

TABLE IV

Mean height of plants in centimeters

Growth regulators	Stages of applications			Mean
	Seed	Seedling	Flowering time	
Control	61.06	61.06	61.06	61.06
NAA 15 ppm.	66.35	72.40	66.40	68.38
NAA 30 ppm.	62.80	68.50	66.60	65.96
Mean	64.57	70.45	66.50	67.17
GA 25 ppm.	63.00	74.10	70.90	69.33
GA 50 ppm.	72.65	69.45	65.30	69.13
Mean	67.87	71.77	68.10	69.23
2, 4-D 2 ppm.	69.05	69.75	72.60	70.46
2, 4-D 5 ppm.	76.40	72.60	67.60	72.20
Mean	72.72	71.17	70.10	71.33
General mean	68.39	71.13	68.24	

Critical difference

i. between treatment combinations - 1.48

ii. between different stages of applitions - 0.604

iii. between growth regulators - 0.604

iv. between different levels of a growth regulator - 0.852

v. between different stages of applications within growth regulator - 1.049

HEIGHT OF PLANTS

The height of plants corresponding to different treatments was analysed and the analysis of variance table is given in table No.III. All the treatments are found to be significant. Mean height of the main stem is given in table No.IV.

A study of the table reveals that the growth regulators increased height of plants significantly. The most vigorous response was produced by 2, 4-D, followed by GA and then NAA, the difference in effect among the growth regulators being significant.

Of the two levels of 2, 4-D applied viz. 5 ppm. and 2 ppm. the higher concentration produced greater height, the difference in effect between the two being significant. Both the levels of GA applied viz. 25 ppm. and 50 ppm. increased height of plants significantly, but the difference in effect between the two levels of GA applied is not significant. However, it is seen that 25 ppm. of GA produced better response than 50 ppm. Application of 15 ppm. and 30 ppm. NAA resulted in significant increases in the height of plants, 15 ppm. being

more effective. The difference in effect between the two treatments is also found to be significant.

Plants at all the stages of applications studied, responded to growth regulators with significant increases in height. Comparing the effect of applications at the different stages, it is found that the seedling spray gave significantly better increases in height than others. Of the other two treatments seed treatments gave slightly better results than 'flower spray', but the difference between these two treatments is not significant.

Application of 2, 4-D to seeds, seedlings, and plants at flowering time produced significantly favourable effects in promoting growth in height of plants. Seeds responded most favourably to application of 2, 4-D and the response was significantly superior to those of seedlings and plants at flowering time. The effect of 2, 4-D on seedlings was found to be better than that produced on plants treated at flowering time, the difference in effect between the two being significant. Applications of GA at all stages studied had resulted in significant increases in height. Seedlings showed significantly better response when compared with seeds and plants at flowering time. The difference in effect

of application of GA on seeds and plants at the time of flowering is not significant. NAA is seen to have significant effects in promoting growth in height at plants at all the three stages studied. Seedlings responded best followed by plants at flowering time and seeds in the order of their superiority. The differences in effect among all the stages are significant.

Weekly observations of height of plants receiving the different treatments are plotted as a curve in Figs. 1, 2 and 3, showing the effect of NAA, GA and 2, 4-D respectively.

From Fig. 1, it is seen that an application of 15 ppm. of NAA to seeds, produced greater height than 30 ppm. throughout the growth period. Application of 30 ppm. NAA to seedlings produced greater growth than 15 ppm. upto about 5½ weeks, after which plants treated with 15 ppm. showed greater height. Growth curve of plants receiving 15 and 30 ppm. is more or less identical, 15 ppm. causing better growth.

Application of 25 ppm. GA to seedlings produced the best response when compared with other treatments with GA and this response was maintained throughout. (Fig.2). Seed treatment with 50 ppm. GA

gave better growth in height when compared with 25 ppm. GA. The superiority of the higher concentration is maintained throughout. Seedlings sprayed with 25 ppm. GA responded with increased height when compared with 50 ppm. Growth is accelerated by the application of 25 ppm. and this acceleration of growth is maintained throughout.

Application of 5 ppm. of 2, 4-D to seeds resulted in better growth in height throughout when compared with all other treatments with 2, 4-D (Fig.3). Seedlings responded with increased height throughout, to applications of 5 ppm., 2, 4-D when compared with application of 2 ppm. However, it is found that 2 ppm. 2, 4-D applied at the time of flowering was superior to 5 ppm. in increasing height of plants.

TABLE V

Analysis of variance table

Number of branches

Source	S.S.	d.f.	Var.	F.
Total	2431.76	134		
Block	54.25	4	13.55	1.52
Treatment	1390.50	18	73.36	8.24**
NAA, GA, 2, 4-D and Control	1091.07	3	363.69	40.86**
Levels of NAA and Control	381.92	2	190.96	21.45**
Levels GA and Control	292.30	2	146.15	16.42**
Levels of 2, 4-D and Control	1061.91	2	530.95	59.65**
Stages of applications and Control	752.60	3	250.86	28.18**
Stages of applications of NAA and Control	373.11	2	186.55	20.96**
Stages of applications of GA and Control	249.91	2	124.95	14.03**
Stages of applications of 2, 4-D and Control	1050.21	2	525.10	59.03**
Error	991.01	112	8.85	

** Significant at 1% level

TABLE VI

Mean number of branches per plant

Growth regulators	Stages of applications			Mean
	Seed	seedling	Flowering time	
Control	3.27	3.27	3.27	3.27
NAA 15 ppm.	4.55	3.60	4.45	4.20
NAA 30 ppm.	4.55	4.80	4.45	4.60
Mean	4.55	4.20	4.45	4.40
GA 25 ppm.	4.40	4.60	4.65	4.55
GA 50 ppm.	3.00	3.65	4.35	3.67
Mean	3.70	4.12	4.50	4.11
2, 4-D 2 ppm.	4.85	5.50	5.75	5.37
2, 4-D 5 ppm.	5.25	5.05	4.70	5.00
Mean	5.05	5.27	5.22	5.18
General mean	4.43	4.53	4.72	

Critical difference

i.	between treatment combinations	-	0.234
ii.	between growth regulators	-	0.096
iii.	between different stages of applications	-	0.096
iv.	between different levels of a growth regulator	-	0.135
v.	between different gtages of applications within growth regulator	-	0.166

NUMBER OF BRANCHES

The number of branches corresponding to different treatments was analysed and the analysis of variance table is given in table No.V. All the treatments are found to be significant in increasing the number of branches. Mean number of branches is given in table No. VI.

From the table it is seen that the number of branches has been significantly increased by the growth regulators. The greatest number of branches was produced by 2, 4-D treatments followed by NAA and GA, the differences in effect among the growth regulators being significant.

Of the two levels of 2, 4-D applied, the lowest concentration viz. 2 ppm. has produced greater number of branches than the higher concentration viz. 5 ppm, the difference in effect between the treatments being significant. Comparing the different levels of GA 25 ppm. has produced greater number of branches than 50 ppm. the difference in effect between the two being significant. Of the two levels of NAA 30 ppm. gave significantly superior results, than the lower concentration

viz. 15 ppm.

Comparing the effect of applications of the growth regulators at different stages, it is seen that 'flower spray' gave significantly better results than others. Of the other two treatments 'seedling spray'is found to be better than seed treatment, the difference between the two being significant.

Comparing the three different stages of applications of 2, 4-D, it is found that seedlings had given better response than the other two treatments, but the difference between the spray application at seedling stage and at flowering time is not significant. Of the different stages at which GA had been applied, application at flowering time produced greater number of branches and was significantly superior to application at other stages. Application of 50 ppm. GA to seeds resulted in decreased number of branches than the control, though the difference in effect is not significant. Of the other two stages studied seedlings gave significantly better response than seeds. Applications of NAA to seeds and plants at flower time were significantly superior to that given to seedlings, in increasing the number of branches.

TABLE VII

Analysis of variance table

Number of nodes

Source	S.S.	d.f.	Var.	F.
Total	145510.00	134		
Block	16179.00	4	4044.75	6.86**
Treatment	63530.80	18	3529.48	5.08**
NAA, GA, 2, 4-D and Control	45908.70	3	15302.90	26.06**
Levels of NAA and Control	17051.00	2	8525.00	14.51**
Levels of GA and Control	5123.00	2	2561.00	4.34*
Levels of 2, 4-D and Control	44134.00	2	22067.00	37.56**
Stages of applications and Control	30886.30	3	10295.40	17.50**
Stages of applications of NAA and Control	16036.30	2	8018.00	13.81**
Stages of applications of GA and Control	9684.70	2	4842.00	8.24**
Stages of applications of 2, 4-D and Control	44624.50	2	22312.00	37.97**
Error	65800.20	112	587.50	

* Significant at 5% level

** Significant at 1% level

TABLE VIII

Mean number of nodes per plant.

Growth regulators		Stages of applications			Mean
		Seed	Seedling	Flowering time	
Control		34.60	34.60	34.60	34.60
NAA	15 ppm.	40.20	38.40	41.60	40.10
NAA	30 ppm.	46.30	42.70	42.30	43.70
Mean		43.25	40.55	41.90	41.90
GA	25 ppm.	39.10	41.20	38.10	39.50
GA	50 ppm.	29.50	42.10	42.10	37.90
Mean		34.30	41.60	40.10	38.70
2, 4-D	2 ppm.	50.70	51.90	42.30	48.30
2, 4-D	5 ppm.	44.30	45.30	46.30	45.30
Mean		47.50	48.60	44.30	46.80
General mean		41.70	43.58	42.10	

Critical difference

i. between treatment combinations - 1.936

ii. between growth regulators - 0.790

iii. between different stages of applications - 0.790

iv. between different levels of growth regulator - 1.118

v. between different stages of applications within a growth regulator - 1.373

TOTAL NUMBER OF NODES

The total number of nodes corresponding to different treatments was analysed and the analysis of variance table is given in table No. VII. The treatments are found to be significant. The mean number of nodes corresponding to different treatments is given in table No. VIII.

From the table it is seen that treatments with growth regulators have produced significant results in increasing the number of nodes. The largest number of nodes was produced by application of 2, 4-D followed by those of NAA and then GA. The differences among these treatments were found to be significant.

Of the two levels of 2, 4-D applied viz. 2 ppm. and 5 ppm. the lower concentration produced greater number of nodes, the difference between the levels being significant. Comparing the two levels of NAA, 30 ppm. produced better response than 15 ppm. the difference between the levels being significant. Both the levels of GA increased the number of nodes significantly. GA 25 ppm. is seen to be significantly superior to 50 ppm.

Comparing the effect of applications of the growth regulators at different stages seedling spray has produced greater number of nodes followed by application at the time of flowering, the difference between the two being significant. But the difference between seed treatment and spray at flowering time is not significant.

Among the three different stages of applications with 2, 4-D seedlings responded best in increasing number of nodes followed by seeds and plants at flowering time. The differences in effect among treatments were significant. Comparing the different stages at which NAA had been applied it is found that seeds responded best in increasing the number of nodes. Of the other two spraying at the time of flowering is better than spraying at the seedling stage. But the difference in effect between the two treatments was not significant. Of the three different stages of applications of GA, seedlings produced largest number of nodes, followed by plants at flowering time, the difference between the two being significant. Application of GA to seeds resulted in decreases in node number. The difference in effect being not significant. But application of 50 ppm. GA to seeds resulted in a significant decrease in effect.

TABLE IX

Analysis of variance table

Fresh weight of stems

Source	S.S.	d.f.	Var.	F.
Total	7138.27	134		
Block	27.60	4	6.90	0.28
Treatment	4155.01	18	230.88	9.54**
NAA, GA, 2, 4-D and Control	3321.61	3	1107.20	45.75**
Levels of NAA and Control	505.32	2	252.66	10.48**
Levels of GA and Control	294.71	2	47.35	1.96
Levels of 2, 4-D and Control	3100.50	2	1550.25	64.05**
Stages of applications and Control	1483.90	3	494.63	20.43**
Stages of applications of NAA and Control	516.12	2	258.05	10.66**
Stages of applications of GA and Control	485.60	2	242.80	10.08**
Stages of applications of 2, 4-D and Control	3267.70	2	1633.85	67.79**
Error	2707.27	112	24.17	

** Significant at 1% level

TABLE X

Mean fresh weight of stems

Growth regulator		Stages of applications			Mean
		seed	seedling	flowering time	
Control		5.50	5.50	5.50	5.50
NAA	15 ppm.	6.88	7.73	6.28	6.96
NAA	30 ppm.	6.45	6.80	7.25	6.83
Mean		6.66	7.26	6.76	6.89
GA	25 ppm.	5.45	7.30	5.84	6.19
GA	50 ppm.	5.60	7.43	5.25	6.09
Mean		5.52	7.36	5.54	6.14
2, 4-D	2 ppm.	9.23	8.45	8.48	8.72
2, 4-D	5 ppm.	10.00	8.35	8.20	8.85
Mean		9.61	8.40	8.34	8.78
General mean		7.24	7.50	6.88	

Critical difference

i.	between treatment combinations	- 0.384
ii.	between growth regulators	- 0.157
iii.	between different stages of applications	- 0.157
iv.	between different levels of a growth regulator	- 0.222
v.	between different stages of applications within a growth regulator	- 0.272

FRESH WEIGHT OF STEMS

The fresh weight of stems corresponding to different treatments was analysed and the analysis of variance table is given in table No.IX. All the treatments are found to be significant except those made with GA on seeds and plants at flowering time. Mean fresh weight of the stem corresponding to different treatments is given in table No. X.

Studying the table it is found that growth regulators had a significant effect in increasing fresh weight of the stems of plants. Among the three growth regulators 2, 4-D produced a better response followed by NAA and GA in the order of their effect, the differences in effect being significant.

Comparing the different levels of 2, 4-D applied 5 ppm. gave slightly greater fresh weight than 2 ppm. though the difference in effect between the two levels was not significant. Of the two levels of NAA applied 15 ppm. gave significantly better increases in fresh weight than 30 ppm. The difference in effect between the two was not significant. Of the two levels of GA 25 ppm. produced slightly better results, though the difference in effect is not significant.

Comparing the three different stages of applications the response of seedlings is significantly superior to others in increasing fresh weight, followed by those of seeds and plants at flowering time in the order of their importance. The differences in effect among all the stages were significant.

Among different stages of applications of 2, 4-D, seeds responded significantly with greater fresh weight, followed by seedlings and then plants at flowering time, The differences in effect among treatments were significant. Of the different stages of applications of NAA seedlings responded best with the highest fresh weight followed by plants at flowering time and seeds in the order of their response. The difference in response exhibited by seedlings and plants at flowering time was significant. However the difference in response shown by seeds and plants at flowering time was not significant. Of the three different stages of applications of GA seedlings gave significantly better response than the other two. The response shown by seeds and plants at flowering time was not significantly different.

TABLE XI

Analysis of variance table

Number of flowers

Source	S.S.	d.f.	Var.	F.
Total	102418.00	134		
Block	482.00	4	120.50	0.22
Treatment	42303.00	18	2350.00	4.41**
NAA, GA, 2, 4-D and Control	22723.80	3	7574.53	14.23**
Levels of NAA and Control	8320.10	2	4160.50	7.82**
Levels of GA and Control	7584.80	2	3792.40	7.13**
Levels of 2, 4-D and Control	22139.00	2	11069.50	20.80**
Stages of applications and Control	22419.50	3	7473.10	14.04**
Stages of applications of NAA and Control	17997.50	2	8998.70	16.91**
Stages of applications of GA and Control	7458.10	2	3729.00	7.00**
Stages of applications of 2, 4-D and Control	22173.40	2	11086.70	20.84**
Error	59663.00	112	532.00	

** Significant at 1% level

TABLE XII

Mean number of flowers per plant

Growth regulators	Stages of applications			Mean
	Seed	seedling	flowering time	
Control	36.5	36.5	36.5	36.5
NAA 15 ppm.	41.3	44.6	41.4	42.4
NAA 30 ppm.	29.6	46.9	47.2	41.2
Mean	35.5	45.8	44.3	41.8
GA 25 ppm.	38.8	40.7	41.9	40.4
GA 50 ppm.	42.5	42.3	43.1	42.4
Mean	40.7	41.5	42.5	41.4
2, 4-D 2 ppm.	46.7	45.0	41.5	44.6
2, 4-D 5 ppm.	44.8	45.3	47.3	45.7
Mean	45.8	45.6	44.4	45.2
General mean	45.8	45.6	44.4	

Critical difference

i. between treatment combinations - 1.808

ii. between growth regulators - 0.738

iii. between different stages of applications - 0.738

iv. between different levels of a growth regulator - 1.043

v. between different stages of applications within a growth regulator - 1.282

Number of Flowers

The number of flowers corresponding to different treatments were analysed and the analysis of variance table is given in table No. XI. All the treatments are found to be significant. Mean number of flowers produced under different treatments is given in table No. XII.

From the table, it is seen that the application of the growth regulators had a striking effect in producing greater number of flowers. Of the three growth regulators 2, 4-D evokes a better response by producing more flowers than NAA or GA the difference in effect among these being significant. However, there is an indication that NAA is better than GA, but the superiority is not significant.

Comparing the different levels of 2, 4-D, 5 ppm. is found to be significantly superior to 2 ppm. in flower production. Of the two levels of NAA, 15 ppm. gave significantly superior results than 30 ppm. Of the different levels of GA, plants receiving 50 ppm. showed significantly better response by producing more flowers than 25 ppm.

Examining the table it is seen that the application of the growth regulators at different stages had increased the number of flowers significantly. Seeds responded with the production of the largest number of flowers and was followed by seedlings. But the difference in response shown by seeds and seedlings was not significant. Plants at these two stages responded significantly better than plants at flowering time.

Of the different stages of application of 2, 4-D seeds responded better with greatest number of flowers followed by seedlings and plants at flowering time. But the differences in effect among the treatments were not significant. Of the different stages of applications of NAA spray at seedling stage produced greatest number of flowers, the effect being significant. Spray at flowering time had also increased the number of flowers significantly. Seed treatments had slightly decreased the number of flowers, though the effect was not significant. But NAA 30 ppm. applied to seeds had significantly decreased the number of flowers. Of the different stages of application of GA application at flowering time gave a slightly better effect than that at seedling stage which was followed by application to seeds, but the differences in effect among the treatments were not significant.

TABLE XIII

Analysis of variance table

Number of fruits

Source	S.S.	d.f.	Var.	F.
Total	105383.00	134	[illegible]	[illegible]
Block	240.00	4	60.00	0.14
Treatment	58444.80	18	3247.00	7.78**
NAA, GA, 2, 4-D and Control	39968.40	3	13322.80	31.94**
Levels of NAA and Control	11409.00	2	5704.50	13.67**
Levels of GA and Control	14606.00	2	7303.00	17.51**
Levels of 2, 4-D and Control	37665.00	2	18832.00	45.16**
Stages of applications and Control	4654.40	3	1551.46	3.72*
Stages of applications of NAA and Control	16269.00	2	8134.00	19.57**
Stages of applications of GA and Control	6371.00	2	3185.50	7.63**
Stages of applications of 2, 4-D and Control	38569.00	2	19284.50	46.27**
Error	46700.00	112	417.00	

* Significant at 5% level

** Significant at 1% level

TABLE XIV

Mean number of fruits per plant

Growth regulators		Stages of applications			Mean
		Seed	Seedling	flowering time	
Control		27.2	27.2	27.2	27.2
NAA	15 ppm.	34.8	36.5	32.5	34.6
NAA	30 ppm.	21.4	36.0	37.4	31.6
Mean		28.1	36.3	34.9	33.1
GA	25 ppm.	32.1	34.0	34.6	33.5
GA	50 ppm.	32.6	34.8	36.9	34.8
Mean		32.4	34.4	35.8	34.1
2, 4-D	2 ppm.	36.6	40.9	37.2	38.2
2, 4-D	5 ppm.	36.8	36.6	43.0	38.8
Mean		36.7	38.8	40.1	38.5
General mean		32.3	36.5	36.9	

Critical difference

i. between treatment combinations - 1.601

ii. between growth regulators - 0.654

iii. between different stages of applications - 0.654

iv. between different levels of a growth regulator - 0.924

v. between different stages of applications within a growth regulator - 1.136

Number of Fruits

The number of fruits corresponding to different treatments was analysed and the analysis of variance table is given in table No. XIII. All the treatments are found to be significant. Mean number of fruits set under each treatment is given in table No. XIV.

From the table it is seen that the application of growth regulators increased the number of fruits. The greatest increase was produced by 2, 4-D followed by GA and NAA in the order of their effect. The differences in effect among treatments were significant.

Comparing the effect of the two levels of 2, 4-D viz. 5 ppm. and 2 ppm., it is found that 5 ppm. was superior to 2 ppm. in increasing the number of fruits set, but the difference in effect between the levels was not significant. Of the two levels of GA 50 ppm. is significantly superior to 25 ppm. Comparing the different levels of NAA it is found that 15 ppm. has produced greater number of fruits than 30 ppm. the difference in number of fruits set, being significant.

Comparing the effect of applications of the growth regulators at different stages it is found that

the greatest number of fruits has been obtained from plants receiving treatment at flowering time, followed by plants receiving treatments at seedling stage and seeds in the order of their response.

Comparing the different stages of applications of 2, 4-D spray at flowering time produced a better response than seedling spray, which is followed by seed treatment. The differences among treatments were significant. Comparing the different stages of applications of GA, spray at flowering time gave better effects, than other treatments. Of the other two stages the effect of application at seedling stage is superior to seed treatment. The differences in effect among all three treatments were significant. Comparing the different stages of applications of NAA spray at seedling stage was significantly superior to other treatments. Seed treatment had slightly favourable effect but this was not significant. But NAA 30 ppm. applied as a pre-sowing treatment had significantly reduced the number of fruits.

TABLE XV

Analysis of variance table

Percentage of fruit-set

Source	S.S.	d.f.	Var.	F.
Total	5467.06	134		
Block	64.34	4	16.09	0.55
Treatment	2190.76	18	121.70	4.24**
NAA, GA, 2, 4-D and Control	1413.44	3	471.14	16.41**
Levels of NAA and Control	222.00	2	111.00	3.86*
Levels of GA and Control	704.00	2	352.00	12.26**
Levels of 2, 4-D and Control	1216.00	2	608.00	21.18**
Stages of applications and control	1336.84	3	445.60	15.52**
Stages of applications of NAA and Control	165.40	2	82.70	2.90**
Stages of applications of GA and Control	759.20	2	379.60	13.22**
Stages of applications of 2, 4-D and Control	1575.00	2	787.50	27.43**
Error	3211.86	112	28.70	

* Significant at 5% level

** Significant at 1% level

TABLE XVI

Mean percentage of fruit-set per plant

Growth regulators		Stages of applications			Mean
		Seed	Seedling	Flowering time	
Control		75.0	75.0	75.0	75.0
NAA	15 ppm.	81.4	80.8	81.2	81.1
NAA	30 ppm.	81.2	77.2	79.8	79.4
Mean		81.3	79.0	80.5	80.2
GA	25 ppm.	83.4	83.6	83.4	83.5
GA	50 ppm.	77.8	77.8	82.0	79.2
Mean		80.6	80.7	82.7	81.3
2, 4-D	2 ppm.	78.6	89.6	90.2	86.1
2, 4-D	5 ppm.	82.0	81.2	91.2	84.8
Mean		80.3	85.4	90.7	85.5
General mean		80.7	81.7	84.6	

Critical difference

i.	between treatment combinations	- 0.421
ii.	between growth regulators	- 0.172
iii.	between different stages of applications	- 0.172
iv.	between different levels of a growth regulator	- 0.243
v.	between different stages of applications within a growth regulator	- 0.299

PERCENTAGE OF FRUIT-SET

The percentage of fruit-set corresponding to different treatments was calculated and by Sin^{-1} transformation converted into degrees and was analysed. The analysis of variance table is given in table No. XV. Treatments were found to be significant. The mean percentage of fruit-set is given in table No. XVI.

From the table it is revealed that growth regulators had a significant effect in increasing the percentage of fruit-set. The maximum with 85.3% fruit-set - corresponds to 2, 4-D treatments, followed by GA with and 81.3% and NAA with 80.2%. The difference in effect caused by different treatments were significant.

Comparing the effect of applications of the growth regulators at different stages, spray at the time of flowering gave the maximum percentage of setting ie. 90.7%, followed by spray at the seedling stage. ie. 81.7% and seed treatment with 80.7%. The differences in effect among treatments were significant.

Comparing the different stages of applica-

tions of 2, 4-D, spray at the time of flowering had resulted in the maximum percentage of fruit-set with 90.7%, which was significantly superior to other treatments. Of the other two, spray at the time of seedling stage was significantly better than seed treatment. Comparing the different stages of applications of GA the spray application at the time of flowering gave maximum percentage of fruit-set with 82.7%. This was followed by seedling spray and then seed treatment. But the difference in effect between spray at seedling stage and seed treatment was not significant. Comparing the different stages of applications of NAA seeds gave significantly superior results, followed by plants at the time of flowering and seedling in the order of their response. The differences among treatments were significant.

Bar diagram (Fig.4) shows the relative fruit-set under different treatments.

TABLE XVII

Analysis of variance table

Yield of seed

Source	S.S.	d.f.	Var.	F.
Total	2246.72	134		
Block	98.17	4	24.54	1.83
Treatment	652.32	18	36.24	2.64**
NAA, GA, 2, 4-D and Control	300.01	3	100.03	7.49**
Levels of NAA and Control	86.50	2	43.25	3.23**
Levels of GA and Control	120.33	2	60.16	4.49*
Levels of 2, 4-D and Control	318.43	2	109.21	8.18**
Stages of applications and Control	428.10	3	142.70	10.68**
Stages of applications of NAA and Control	217.13	2	108.56	8.13**
Stages of applications of GA and Control	108.03	2	54.01	4.04*
Stages of applications of 2, 4-D and Control	356.73	2	178.36	13.36**
Error	1496.23	112	13.35	

* Significant at 5% level

** Significant at 1% level

TABLE XVIII

Mean yield of seed per plant (in gms.)

Growth regulators		Stages of applications			Mean
		Seed	Seedling	Flowering time	
Control		2.81	2.81	2.81	2.81
NAA	15 ppm.	3.23	3.96	3.24	3.47
NAA	30 ppm.	1.99	3.88	3.69	3.19
Mean		2.61	3.92	3.46	3.33
GA	25 ppm.	3.16	3.92	3.50	3.53
GA	50 ppm.	3.11	3.33	3.73	3.39
Mean		3.14	3.63	3.61	3.46
2, 4-D	2 ppm.	3.47	4.36	4.09	3.97
2, 4-D	5 ppm.	3.43	3.57	4.25	3.75
Mean		3.45	3.96	4.17	3.86
General mean		3.07	3.84	3.75	

Critical difference

i.	between treatment combinations	- 0.287
ii.	between growth regulators	- 0.117
iii.	between different stages of applications	- 0.117
iv.	between different levels of a growth regulator	- 0.165
v.	between different stages of applications within a growth regulator	- 0.204

YIELD OF SEEDS

The yield of seeds corresponding to different treatments was analysed and the analysis of variance table is given in table No. XVII. The treatments are found to be significant. The mean yield of seed, under each treatment is given in table No. XVIII.

A study of the table reveals that growth regulators had significantly increased the yield of seeds. The most marked response was evoked by 2, 4-D treatments with an yield of 3.86 gms./plant followed by GA and NAA in the order of their effect.

Comparing the effect of two levels of 2, 4-D viz. 5 ppm. and 2 ppm., the highest seed weight ie. 3.97 gms. was obtained from plant treated with the lower concentration. Of the two levels of GA, 25 ppm. gave significantly superior results over 50 ppm. Comparing different levels of NAA, 15 ppm. gave greater yield of seeds than 30 ppm., the difference in effect being significant.

Comparing the effect of application of the growth regulators at the three stages it is found that application to the seedlings gave the highest yield with

3.84 gms. per plant followed by spray at the time of flowering, and seed treatment in the order of their effect. The differences in effect among the treatments were significant.

Comparing the effect of different stages of applications of 2, 4-D, plants at flowering time gave significantly superior response over other stages with an yield of 4.17 gms. followed by seedlings and seeds in the order of their response. Comparing the different stages of application of GA to plants, seedlings gave a better response followed by spray at flowering and seed treatment. The differences in effect among treatments were significant. Of the different stages of applications of NAA, seedlings were found to respond best with an yield of 3.92 gms. per plant. Spray at flowering was better than seed treatment in increasing the yield of seeds. The differences in effect among the three treatments were significant. NAA, 30 ppm. applied to seeds had decreased the yield of seeds significantly.

Fig. 5 A shows the mean yield of seeds corresponding to different treatments.

TABLE XIX

Percentage of oil content

S.No.	Tt.No.	Details of the treatments	Mean percentage of oil content
1	1	Control	50.00
2	4	NAA 15 ppm. seed treatment	37.88
3	5	NAA 15 ppm. 'seedling spray'	42.50
4	6	NAA 15 ppm. 'flower spray'	43.50
5	7	NAA 30 ppm. seed treatment	31.25
6	8	NAA 30 ppm. 'seedling spray'	32.00
7	9	NAA 30 ppm. 'flower spray'	37.25
8	13	GA 25 ppm. seed treatment	42.75
9	14	GA 25 ppm. 'seedling spray'	44.50
10	15	GA 25 ppm. 'flower spray'	47.30
11	16	GA 50 ppm. seed treatment	40.50
12	17	GA 50 ppm. 'seedling spray'	41.50
13	18	GA 50 ppm. 'flower spray'	40.50
14	22	2, 4-D 2 ppm. seed treatment	37.25
15	23	2, 4-D 2 ppm. 'seedling spray'	39.25
16	24	2, 4-D 2 ppm. 'flower spray'	41.50
17	25	2, 4-D 5 ppm. seed treatment	40.00
18	26	2, 4-D 5 ppm. 'seedling spray'	42.13
19	27	2, 4-D 5 ppm. 'flower spray'	42.75

TABLE XX

Percentage of oil content in the order of merit

Rank.	Tt.No.	Details of the treatments.	Mean percentage of oil content
1	1	Control	50.00
2	15	GA 25 ppm. 'flower spray'	46.13
3	14	GA 25 ppm. 'seedling spray'	44.50
4	6	NAA 15 ppm. 'flower spray'	43.50
5	13	GA 25 ppm. seed treatment	42.75
5	27	2, 4-D5 ppm. 'flower spray'	42.75
6	5	NAA 15 ppm. 'seedling spray'	42.50
7	26	2, 4-D5 ppm. 'seedling spray'	42.13
8	17	GA 50 ppm. 'seedling spray'	41.50
8	24	2, 4-D2 ppm. 'flower spray'	41.50
9	16	GA 50 ppm. seed treatment	40.50
9	18	GA 50 ppm. 'flower spray'	40.50
10	25	2, 4-D5 ppm. seed treatment	40.00
11	23	2, 4-D2 ppm. 'seedling spray'	39.25
12	4	NAA 15 ppm. seed treatment	37.88
13	9	NAA 30 ppm. 'flower spray'	37.25
13	22	2, 4-D2 ppm. seed treatment	37.25
14	8	NAA 30 ppm. 'seedling spray'	32.00
15	7	NAA 30 ppm. seed treatment	31.25

OIL CONTENT IN SEEDS

The mean percentage of oil content in seeds is given in table No. XX. Fig.7 provides a comparative study of the oil content of the treatments with control.

It is seen from the table that application of growth regulators at all stages adversely affect oil content of seeds.

The reduction in oil content was mostly marked in the case of applications of 30 ppm. NAA given to seeds. The percentage of oil content of seeds was as low as 31.25% whereas in the control it was 50%. This reduction of 18.75% in oil content was closely followed by that in plants treated with 30 ppm. NAA at seedling stage.

The lowest reduction in oil percentage among treated plants was obtained from plants treated with 25 ppm. GA at flowering time which showed an oil content of 46.13%. The reduction in oil content was found to be 3.87%. When compared with the reduction caused by application of NAA 30 ppm. given to seeds, the above value is low. However even this low value is large enough to be of importance.

All other treatments resulted in reducing the oil content which varied between the two extremes of 31.25% and 46.13%.

Fig. 8.B. shows the oil content in percentage corresponding to different treatments.

DISCUSSION

DISCUSSION

Investigations on the effect of growth regulators on germination, growth, flowering, fruiting and final yield in various plants carried out in different countries had not shown uniform results. The effects of growth regulators varied from harmful through no effect to beneficial effects.

1. Percentage of germination:

The first observation made during this investigation was the significantly higher percentage of germination produced by all the treatments, except NAA 30 ppm. which had only an adverse effect.

The results of the present study show that application of NAA 15 ppm. increases the germination percentage of seeds of Sesamum by 6.50%. But NAA at a concentration of 30 ppm. is found to have retarded the percentage of germination. Promotive effects of NAA were previously reported by Narasimha Rao et al., (1957) in ground nut, Chatterjee (1960) in Aleurites fordii and Gandhi and Bhatnagar (1961) in Cuminum cyminum. But Gandhi and Bhatnagar (1961) also found that NAA at higher concentrations did not promote the percentage of germina-

tion in Cuminum cyminum. In support of this was the findings of Kumara Pillai (1963) that pre-soaking treatment of the seeds of bittergourd and green grams with NAA at still higher concentrations inhibited germination. The adverse effects of NAA on germination noted may possibly be due to the relatively higher concentration used.

Gibberellic acid treatments increased the percentage of germination of Sesamum seeds in the present study. Similar results were obtained by other workers also. Germination percentage was increased by GA treatments in seeds of wild oats (Helgeson and Green, 1957), Anemone coronoeaster and Primula (Tod, 1958), Kok-saghys and broad-bean seeds (De Lean and Derafols, 1959), lettuce, spinach, egg plant, radish, marrow, bean, carrot and onion (Pisani, 1959), lettuce (Skinner, Talbert and Shive 1959) and Lycopersicum esculentum (Choudhury and Singh 1960). De Leon and Derafols (1959) found that germination was not accelerated above a concentration of 5 ppm., GA in Kok-saghys and broad bean seeds. But Mazzani and Gonzales, (1959) reported that germination of Sesame, bean, tomato, and papaw seeds was unaltered by seed treatment with gibberellin. A general decrease in germination of paddy treated with GA is reported by Vinodhini Vasudevan

and Moosa Sheriff (1963). They also state that certain concentrations of GA completely prevents the germination of paddy seeds. But the present work on sesamum shows that the two concentrations of GA (25 and 50 ppm.) tried invariably promoted the percentage of germination.

In the present study greatest increase in germination percentage was obtained by 2, 4-D treatments in both the concentrations, 2 and 5 ppm. used. This is in agreement with the findings of Hsueh and Lou (1947) in rice and barley, and Choudhury and Singh (1960) in Lycopersicum esculentum. But these two workers also observed inhibitory effects when relatively higher concentrations of GA were used.

In the present work higher concentrations of NAA was found to retard the rate of germination. This is perhaps in accordance of the theory on auxin action proposed by Skoog, 1951. According to this theory the auxin molecules act as co-enzymes and serve as points of attachment between the enzymes controlling growth and their respective substrates. At high concentrations auxin molecules combine separately with the enzyme and the substrate, making their proper union difficult.

The results of past work and the present study

indicate that the effect of growth regulators on germination mainly depends on factors such as the nature of the seed material, growth regulator used, and the concentration of the growth regulators.

2. Height of plants:

In the present study it was noticed that the height of plants significantly increased by treatment with growth regulators at various stages. The greatest increase in height had been obtained by 2, 4-D treatments, followed by GA and NAA.

Application of NAA at all stages viz. seed, seedling and flowering time had increased height of plants. Seedlings responded best to application of NAA. The increase in height following treatments with NAA had been previously reported by many workers. Singh (1957) obtained increased growth in tomato and Coleus seedlings by spray application with NAA.

But there is difference of opinion regarding the effect of pre-sowing treatment with NAA. Chatterjee (1960) obtained healthy seedlings in Aleurites fordii when seeds were treated with NAA. Contradicting to this Narayanan and Vasudeva Menon (1960) found that pre-sowing

treatment with NAA in ragi, did not affect the plant height. In the present study seed treatment of Sesamum with NAA had defenitely enhanced the growth of the plant, but not to such an extent as in the case of seedling treatment.

The outstanding effect of GA on plants, the elongation of the shoot, has also been obtained in the present study. Plants receiving 25 ppm. GA sprays at seedling stage had an increased height of 13 cms. above the control plants. Increased shoot elongation by spray application of GA had been reported earlier in Sesamum indicum (Chakravarthi, 1956), dwarf varieties of peas (Brian and Hemming, 1956), lettuce (Doljakoff Mayber and Mayer 1959), tomato (Rappaport, 1957, 1961), strawberry (Singh, Randhawa and Jain 1960) and four varieties of mesta (Appalanaidu and Satyanarayanamurthy, 1962). According to Chakravarrthi (1956) and Appalanaidu and Satyanarayanamurthy (1962) the increased height was caused by internodal elongation. In the present investigation the number of nodes were also found to increase along with the increase in internodal length. Therefore the increase in height of the plant may partly be due to the increase in number of nodes also.

Another striking feature noted when GA sprays were given at seedling stage, was that, there was a sudden increase in height of plants for about two weeks immediately after the spray and after that the growth rate returned to normal. This is represented as growth curve of GA treated plants (in Fig.2).

In agreement with the findings of Gray (1956) in cherry, Moore (1958) in pea, Mazzani and Gonzalez (1959) in sesame, bean, tomato and papaw and Vinodhini Vasudevan and Moosa Sheriff (1963) in Paddy, the present study revealed that pre-sowing treatment with GA had also resulted in increased height of the plants. But the increase was not conspicuous as that of the seedling treatment.

Greatest increase in height of plants had been recorded in the case of 2, 4-D treatments. Both the concentrations used, 2 and 5 ppm. promoted the shoot length significantly. Plants receiving pre-sowing treatment with 2, 4-D 5 ppm. attained the greatest height and registered an increase of 15.34 cms. over the control. Such effects of low concentrations of 2, 4-D had been reported by Choudhury and Singh (1960) in Lycopersicum esculentum. However 2, 4-D at concentration 100-5000 ppm. had been

found to be harmful in Brassica and Okra by Appalanaidu (1959).

It is perhaps interesting to note that the height attained by GA treated plants was comparatively less than that of plants treated with 2, 4-D. Although hyper elongation of internodes is the most striking effect of GA it cannot be considered as a general rule. Varying responses exhibited by different plants to gibberellic acid treatments might well explain the comparatively feeble response shown by the plants treated with GA, in this study.

3. Number of branches:

In the present study the number of branches had been significantly increased by treatment with all levels of growth regulators except GA 50 ppm. applied as pre-sowing treatment.

NAA treatments in general had increased the number of branches. Greatest increase had been produced by NAA 30 ppm. sprayed at seedling stage.

GA treatments increased the number of branches except in the case of GA 50 ppm. seed treatment. Greatest number of branches had been produced by GA 25 ppm. when applied as spray on seedlings and at the time of flowering.

Increase in number of branches by GA had been reported by many workers such as Thorup (1959) in Coleus, Singh, Randhawa and Jain (1960) in strawberry and Appalanaidu and Satyanarayanamurthy (1963) in mesta.

The greatest increase in number of branches had been produced by 2, 4-D treatments, especially at the lower concentration, 2 ppm., when sprayed at the seedling stage and at flowering time.

4. Number of nodes:

In the present enquiry, the total number of nodes in plants had been significantly increased by treating with growth regulators at different stages except for seeds treated with GA 50 ppm. The greatest increase in number of nodes had been obtained by 2, 4-D treatments followed by NAA and GA. In all the treatments with NAA number of nodes were increased significantly. Greatest increase was noted in plants receiving pre-sowing treatment with NAA 30 ppm. This can be attributed to the increased number of branches in this treatment, eventhough the height in this treatment is less than those in other treatments.

In the present study the total number of nodes

had been increased by GA treatments, except 50 ppm. seed treatment. Greatest increase in number of nodes had been obtained by spray application of GA 50 ppm. at seedling stage and at the time of flowering. This has been supported by the findings of Bonde and Moore (1959). They obtained increased number of nodes by GA sprays in telephone peas.

The greatest increase in number of nodes had been effected by 2, 4-D treatments, especially by 2 ppm. seed treatment.

Increase in the number of nodes denotes increase in the number of leaves and the possibility of increase in the number of flowers, thereby increasing the yield of the plant.

5. Fresh weight of the stem:

Most of the treatments employed under the present investigation increased the fresh weight of the stem. The greatest increase in fresh weight of stem was obtained by 2, 4-D treatments, followed by NAA and GA.

NAA treatments at both the concentrations used, viz. 15 ppm. and 30 ppm. increased the fresh weight of

stem. The greatest fresh weight of stem was noticed in the treatment 15 ppm. 'seedling spray'. This increase in fresh weight was not due to increase in branching, since the number of branches in these treatments were found to be less.

In the case of GA, seedling spray alone had increased the fresh weight of the plants significantly. This has been supported by Brian and Hemming (1956) im dwarf varieties of peas, where increase in fresh weight had been obtained by spray application of GA at seedling stage. Increase in fresh weight resulting from spray application of GA had also been reported in celery (Bukovac and Wittwer, 1957) and lettuce, parsley, onion and garlic (Mosolov and Mosolova, 1959). But Ogzewalla (1961) obtained reduction of fresh weight in peppermint by spray application of GA.

Greatest increase in fresh weight of the plants receiving spray at seedling stage may be due to the greater number of branches and increased height than plants receiving other treatments. The lesser fresh weight noted in plants receiving other treatments was also accompanied by reduction in height and number of branches.

Greatest increase in fresh weight had been produced by 2, 4-D treatments, particularly in plants receiving pre-sowing treatment with 2, 4-D 5 ppm. As the same treatment was most effective in increasing the number of branches, as well as, the height of the plants, this result can naturally be expected. Of the different stages of applications of 2, 4-D lowest increase in fresh weight was recorded following the spray treatment at the time of flowering. In plants receiving this treatment, increase in height and number of branches were not as much as in the case of other treatments with 2, 4-D.

6. Number of flowers:

Treatment with growth regulators had increased the number of flowers in all treatment except in plants receiving pre-sowing treatment with 30 ppm. NAA. The greatest increase in number of flowers had been caused by 2, 4-D treatments, followed by NAA and GA.

All the plants receiving treatment with NAA at different stages, except pre-sowing treatment with 30 ppm. NAA, increased the number of flowers over the control. Greatest increase had been produced by treatments receiving a spray of NAA 30 ppm. at the flowering

time. This has been supported by the findings of other workers. Leopald and Thimann (1949) were able to increase the number of flowers in barley by a weak solution of NAA. However, Ueno (1956) in strawberries observed that NAA applied at higher concentration before flower formation inhibited flowering. The greatest number of flowers produced by the plants receiving NAA 30 ppm. at flowering time indicates that NAA promotes flowering in Sesamum.

All the gibberellic acid treatments employed in the present study increased the number of flowers. The greatest increase in number of flowers had been obtained by the treatments receiving spray at flowering time, particularly 50 ppm. Similar results of stimulation of flowering had been obtained by Thorup(1959) in Cleome monophylla, Tagetes patula and Pelargonium zonale and by Itakura Shiraki, Y., and Shiraki, S. (1959) in petunia, pansy, cyclaman, hydrangia, narcissus, Primula malacoides and Adonis amurensis. Chakravarthi and Abraham (1959) found that GA at 1, 10 and 100 ppm. applied as pre-sowing treatment of seeds or as foliar sprays did not hasten flowering, but repeated treatments with 100 ppm. delayed flowering. In the present study, there was no hastening

of flowering, but the number of flowers had been increased.

Among GA treatments greatest number of flowers had been produced by spray application of GA 50 ppm. at the time of flowering. As the number of branches and height of plants in these treatmentswere lesser than other GA treatments, the greater number of flowers produced may be due to the effect of GA in promoting flowering.

Greatest number of flowers had been produced by 2, 4-D treatments. This confirms the reports of other workers. Van Overbeek (1946) reported that induction of flowering in pine apple can be made possible by spray application of 5 ppm. 2, 4-D.

Greatest increase in the number of flowers had been produced by 5 ppm., 2, 4-D sprayed at flowering time and 2 ppm. treated on seeds. This increase in the number of flowers may be due to production of more branches, nodes and increased height of plants. But as the number of branches produced was greater for other 2, 4-D treatments, increase in number of flowers in this particular treatment cannot be attributed to the increased number of branches. But the effect of 2, 4-D in promoting more number of flowers is evident.

From a perusal of results, it is seen that in general spray application at the time of flowering had more effect in production of flowers and setting of fruits, than promoting the vegetative growth.

7. Number of fruits:

In the present investigation the number of fruits had been increased by treatment with growth regulators except in the case of NAA 30 ppm. seed treatment. The greatest number of fruits was obtained from 2, 4-D treatments.

NAA treatments increased the number of fruits over control, except in plants receiving pre-sowing treatment with 30 ppm. The greatest increase among NAA treatments had been achieved by NAA 30 ppm. when applied at flowering time and by 15 ppm. when applied as seedling spray. This is in agreement with the findings of Luckwill (1953) in apples, Crane and Bradley (1956) in apricots and Kepkowa (1959) in tomato. Ueno (1956) found that NAA at higher concentrations inhibited fruiting in strawberries. Marsh, Southwick and Weeks (1961) found that NAA reduced fruit-set in apples. NAA 15 ppm. seed treat-

ment increased the number of flowers over control, while 30 ppm. decreased. The promotive effects had been confirmed by Gandhi and Bhatnagar (1961) in Cuminum cyminum where the total yield was increased by a 10 ppm. NAA solution as pre-sowing treatment.

Among NAA treatments greatest number of fruits were obtained from treatments with NAA 30 ppm. sprayed at seedling stage, and at flowering time and from NAA 15 ppm. applied to seedlings. This increase in number of fruits was due to production of more flowers along with an increased percentage of setting.

All the GA treatments had increased the number of fruits over control. Greatest increase in number of fruits had been obtained from treatments receiving spray application at the time of flowering and at seedling stage. Similar reports had been published by various workers. Krimbas, Davidas and Michailidis (1959) in black corinth grapes obtained increased yield of fruits, resulting from spray application of GA. Increased yield of fruits resulting from a greater setting had been reported by Randhawa and Singh (1959) in Pusa seedless variety of grapes. Randhawa, Singh and Khana (1959) in phalsa, Randhawa, Singh and Dhuria (1959) in sweet lime, Gustafson (1960) in tomato and Lawrence Rappaport and Singh (1961) in

tomato. But Bukovac, Larsoen and Bell (1960) found that in concord grapes, total number of fruits was not affected by GA sprays, in conflicting with the results obtained here.

Greatest number of fruits among the GA treatments were produced by plants receiving spray of 50 ppm. GA at the time of flowering, and seedling stage and then plants receiving 25 ppm. GA sprays at the time of flowering. This was due to the production of greater number of flowers, along with increased percentage of setting in these treatments. But in plants receiving pre-sowing treatment of GA 50 ppm., the number of flowers produced was greater, but the setting compared with other treatments receiving spray was less.

In the present investigation greatest number of fruits had been obtained from plants receiving spray application at the time of flowering and seedling stage. Similar results had been obtained by Stewart and Parker (1954) in grapes, Krishnamurthy and Subramaniyan (1954) in brinjal, Krjackov (1956) in tomato, Crane and Bradley (1956)in Steward apricots, Muthukrishnan (1957) in brinjal, Randhawa, Sharma and Jain (1961) in Sweet orange varieties and Abdul Ravoof (1963) in Sapota.

The greatest number of fruits among 2, 4-D treatments had been produced from treatments receiving spray of 2, 4-D 5 ppm. at flowering time and 2 ppm. at seedling stage. The greatest number of fruits in these treatments was due to an increase in flower production and setting. But in the case of 2, 4-D 2 ppm., the number of fruits was less when compared with other treatments, eventhough flower production was greater when compared with other treatments. It is therefore evident, that growth regulators has a striking effect in increasing the number of fruits, when applied as sprays, especially at flowering time.

8. Percentage of fruit-setting:

In the present enquiry, in all the treatments the percentage of fruit-setting had been increased over control by treating with growth regulators. The maximum increase in percentage of fruit-setting had been attained in 2, 4-D treatments followed by GA and then NAA.

In NAA treatments the percentage of fruit-setting had been increased in all the treatments. The maximum increase was produced in treatments receiving

pre-sowing treatment and spray at the time of flowering. Greater production due to an increase in the percentage of setting by application of growth regulators at the time of flowering had been reported by various workers. Luckwill (1953) in apples reported increased fruit-set by an application of NAA. But as opposing to this, reduction of fruit-set was noticed by Marsh, Southwick and Weeks (1961) in apples by NAA sprays.

Effect of NAA in increasing the fruit-set is an accepted fact and this has been confirmed here also.

All the treatments of GA increased the percentage of fruit-set over control. The greatest increase had been noticed when GA sprayed at flowering time. This is in agreement with the findings of various other workers. Krishnamurthy, Randhawa and Singh (1959) in Pusa seedless variety of grapes (Vitis vinifera L.), Randhawa, Singh and Khana (1959) in phalsa, Randhawa, Singh and Dhuria (1959) in sweet lime, Gustafson (1960) in tomato and Lawrence Rappaport and Singh (1961) in tomato, obtained increased percentage of fruit-set by floral sprays of GA.

Maximum increase in percentage of fruit-setting had been obtained when GA applied as 'flower sprays'. Effect of GA in increasing the percentage of fruit-set is

confirmed in the present study also.

Maximum increase in the percentage of fruit-set had been obtained by 2, 4-D treatments, especially when applied at the time of flowering. A maximum fruit-set of 91.2% had been achieved when 2, 4-D 5 ppm. was sprayed at the time of flowering.

This is in agreement with the findings of various workers who obtained increased percentage of fruit-set by spray application at the time of flowering. Krishnamurthy and Subramaniyan (1954) in brinjal, Muthukrishnan (1957) in brinjal, Randhawa, Singh and Dhuria (1959) in sweet lime, obtained increased percentage of fruit-set by low concentrations of 2, 4-D when applied at the time of flowering.

In the present study both the concentrations viz. 2 ppm. and 5 ppm. when applied at the seedling stage and as pre-sowing treatment, the percentage of fruit-set was increased over the control. Effect of 2, 4-D in increasing fruit-set, when applied to plant at low concentrations has been confirmed in this study also.

9. Yield of seeds:

As a result of treatment with growth regulators the yield of seed had been increased in most of the treatments. Greatest increase had been obtained in 2, 4-D treatments, followed with GA and NAA.

In all the treatments with NAA, except with 30 ppm. seed treatment, the yield of seed had been increased. An increase in seed production in cururbits and tomatoes resulting from spraying with NAA at the time of flowering had been reported by Takashima, Izuta and Kitao, (1957). But Marsh, Southwick and Weeks (1961) reported that in apples NAA sprays after petal fall had no effect in the number of seeds.

The maximum yield of seeds among NAA treatments had been obtained in plants receiving NAA 15 ppm. spray at the seedling stage. But greatest number of fruits had been produced by plants receiving NAA 15 ppm. spray at the time of flowering. Hence there is evidence to believe that in this treatment there may be parthenocarpic fruit-set also. But in plants receiving pre-sowing treatment with NAA 30 ppm. the yield was very low and was

directly related to the low production of fruits.

The yield of seeds of all the GA treatments had increased over the control. The greatest increase had been noted in plants receiving spray application at the seedling stage and at the time of flowering. Increase in seed production had been reported by Bukovac and Wittwer (1956) in several varieties of lettuce, mustard and radish. But Muromcev and others (1960) obtained no seed-set by spray application of GA to seedlings of carrot, turnip and radish.

The greatest yield of seed had been obtained from treatment with GA 25 ppm. to seedling. This was due to the greater number of fruits produced by this treatment.

The greatest increase in yield among all treatments, were from that of 2, 4-D, especially 2 ppm. when applied to the seedlings and 5 ppm. when applied at flowering time. Taguchi and Nishiri (1956) obtained seed-set by 2, 4-D treatments even in varietal crosses of potato.

Eventhough 2, 4-D 2 ppm. applied to seedlings gave greater yield of seeds than 2, 4-D 5 ppm.

applied to plants at the time of flowering, the greater number of fruits were produced by the latter treatment. Hence there is evidence to believe that there may be parthenocarpic fruit-set. But in the case of seed treatments the yield of seeds was low and was related directly to the production of less number of fruits, compared to other 2, 4-D treatments.

10. Oil-content:

It has been found that in all the treatments with growth regulators, the oil content had been decreased. The lowest value in oil percentage viz. 31.25% had been noticed in NAA 30 ppm. seed treatment, where as seeds from controls had 50% oil. Plants treated with 25 ppm. GA at flowering time which showed an oil content of 46.13% was the least affected of all treatments. All the other treatments resulted in reducing the oil content which varied between 31.25% and 46.13%.

Yermanos and Knowles (1960) reported depression of oil content in safflower by treating with 10 and 100 ppm. GA at flowering time which is in confirmation with the results obtained in the present study.

Reduction of oil content in flax by the application of 2, 4-D had been reported by Tandon (1949), and Paatela (1949). These reports are in agreement with the results obtained in the present study. But contradicting to this, Klosterman and Clagett (1948) obtained no significant difference in oil percentage in flax.

Though the oil content had been reduced by the treatments the yield had significantly increased. From the present study it is revealed that this decrease in oil content is compensated with the increased yield. Whether this increased yield compensates the reduction in oil content on an acre basis has to be further investigated.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

An experiment was conducted at the Agricultural College and Research Institute, Vellayani during 1962-63, to study the effect of three growth regulators - NAA, GA and 2, 4-D on germination, growth and oil content of Sesamum indicum.

NAA, GA and 2, 4-D at three different levels 0, 15, 30; 0, 25, 50; and 0, 2, 5 ppm. respectively, were tried for the present study. The three different stages of application were seed, seedling and at the time of flowering. The experiment was conducted as pot-culture in randomised block design with 5 replications and 27 treatments in factorial combinations.

Observations on germination percentage, height of plants, number of branches and nodes, fresh weight of stem, number of flowers and fruits, percentage of fruit-setting, yield and oil contents of seeds were recorded and the data statistically analysed. The following results were obtained.

Germination percentage was studied separately under laboratory conditions with 7 treatments replicated

4 times. All the treatments except NAA 30 ppm. increased the germination percentage significantly. Maximum increase in germination percentage had been obtained from 2, 4-D treatment, 5 ppm.

Height of the plants were found to increase by all the treatments. The greatest increase being observed in treatments with 2, 4-D followed by NAA and GA.

Number of branches had been increased by treatments with growth regulators except in plants receiving pre-sowing treatment with GA 50 ppm. Greater number of branches had been produced by 2, 4-D treatments.

There was a significant increase in the number of nodes in all the treatments except pre-sowing treatment with 50 ppm. Here also 2, 4-D gave the maximum number of nodes.

Fresh weight of the stem was found to increase in all treatments except in the case of GA applied to seeds. Greatest increase in fresh weight was noted in 2, 4-D treatments.

Number of flowers were found to increase by treatments with growth regulators except in plants receiving pre-sowing treatment with NAA 30 ppm. More flowers were produced by 2, 4-D than by any other treatments; followed by NAA and GA.

In all treatments except the pre-sowing treatment, NAA 30 ppm. there was a significant increase in the number of fruits. Greatest number of fruits was obtained from 2, 4-D treatments, followed by GA and NAA.

Percentage of fruit-set had been increased by treatment with growth regulators. The highest percentage noticed was 90.7% in plants receiving 2, 4-D spray at the time of flowering.

The maximum yield of seeds was obtained in treatment with 2, 4-D. Only in one treatment NAA 30 ppm. seed treatment, the yield was less than that of the control. Next to 2, 4-D, GA and NAA were found to promote more yield of seeds.

A general fall in the oil content of the seeds of the treated plants was noticed. The decrease in oil-content was more conspicuous in seed treatment with NAA 30 ppm.

The study conducted on the effect of NAA, GA and 2, 4-D on Sesamum indicum, reveals that growth regulators applied at different stages of the plant growth, in-

cluding seed treatment increase the germination percentage, general vigour, flowering and fruit-setting thereby increasing the total yield of the plant. Seed treatment with comparatively higher concentration of NAA - 30 ppm. alone is found to deteriorate the yield of the plant.

The oil content of the seeds of treated plants is found to decrease. This decrease in oil-content is however more than compensated by increased yield of the treated plants.

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ILLUSTRATIONS

FIGURE 1

Growth curve showing the height of NAA treated plants

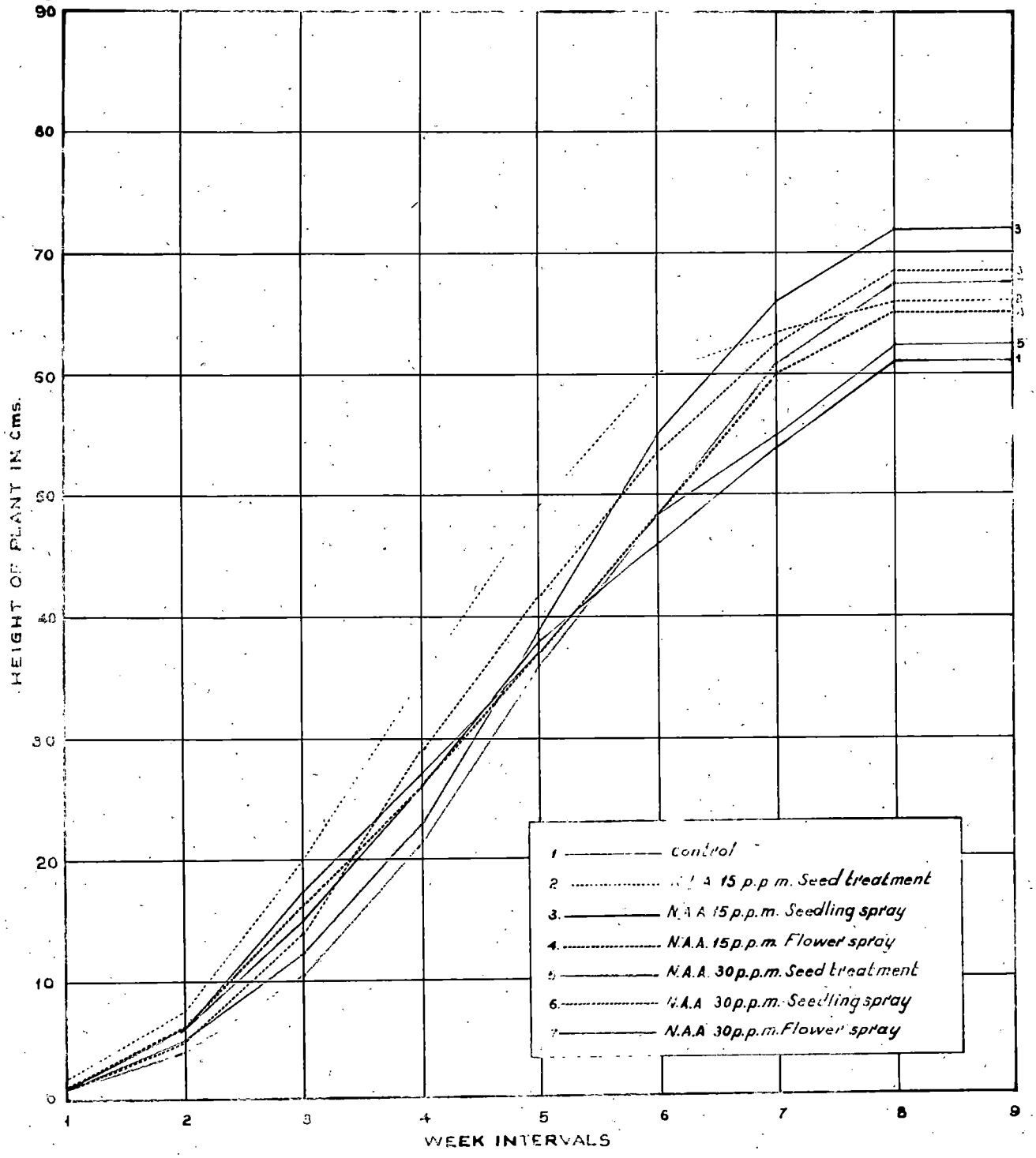

90
80
70
60
50
40
30
20
10
0
HEIGHT OF PLANT IN Cms.
1
2
3
4
5
6
7
8
9
WEEK INTERVALS
1 ——— Control
2 ..... N.A.A 15 p.p.m. Seed treatment
3. ——— N.A.A 15 p.p.m. Seedling spray
4. ..... N.A.A. 15 p.p.m. Flower spray
5 ——— N.A.A. 30 p.p.m. Seed treatment
6. ..... N.A.A 30 p.p.m. Seedling spray
7 ——— N.A.A 30 p.p.m. Flower spray

FIG. 1

FIGURE 2

Growth curve showing the height of

GA treated plants

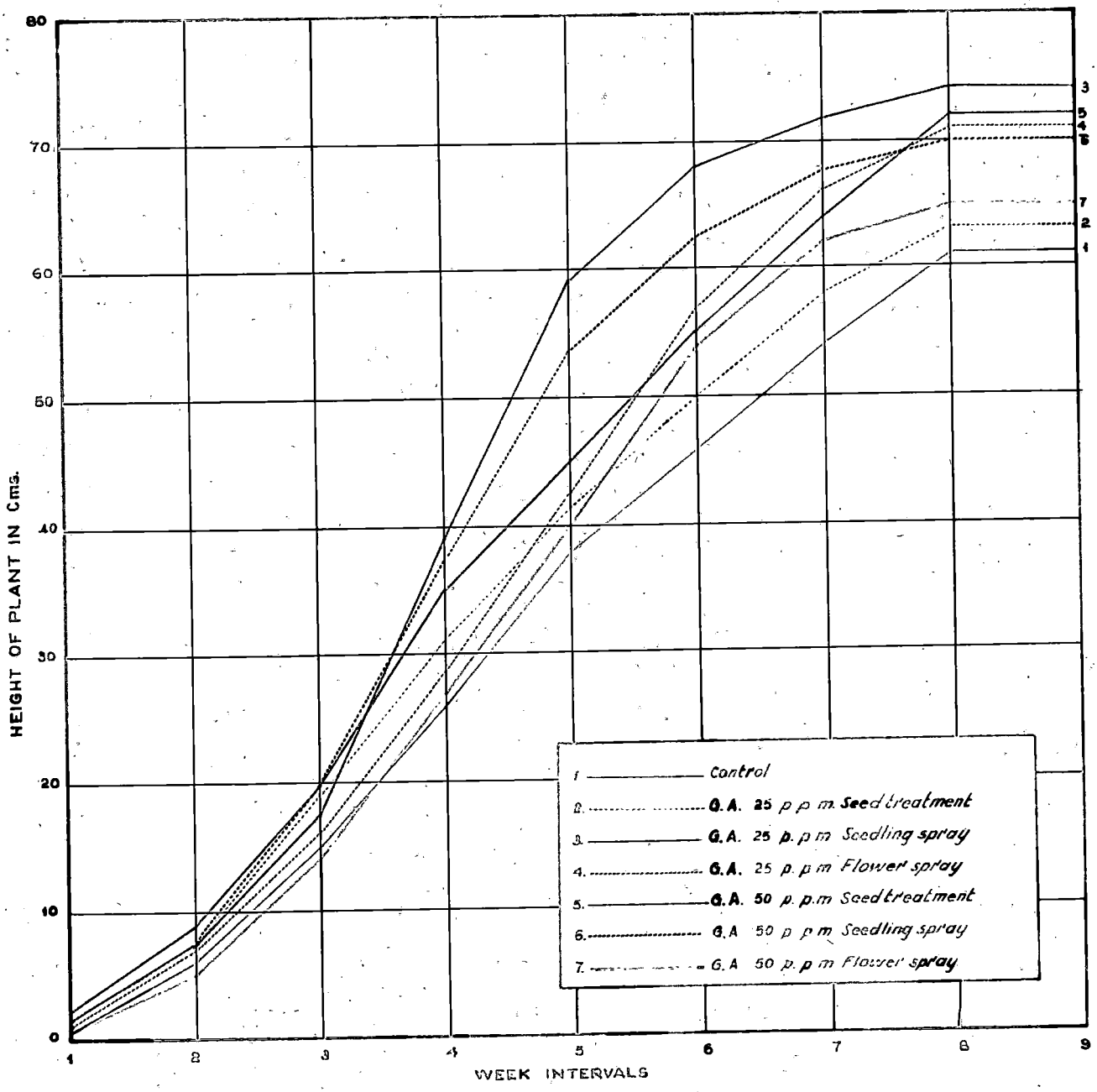

80
70
60
50
40
30
20
10
0
HEIGHT OF PLANT IN Cms.
1
2
3
4
5
6
7
8
9
WEEK INTERVALS
3
5
4
6
7
2
1
1 Control
2 G.A. 25 p.p.m. Seed treatment
3 G.A. 25 p.p.m Seedling spray
4 G.A. 25 p.p.m Flower spray
5 G.A. 50 p.p.m Seed treatment
6 G.A 50 p.p.m Seedling spray
7 G.A 50 p.p.m Flower spray

FIG. 2

FIGURE 3

Growth curve showing the height of

2, 4-D treated plants

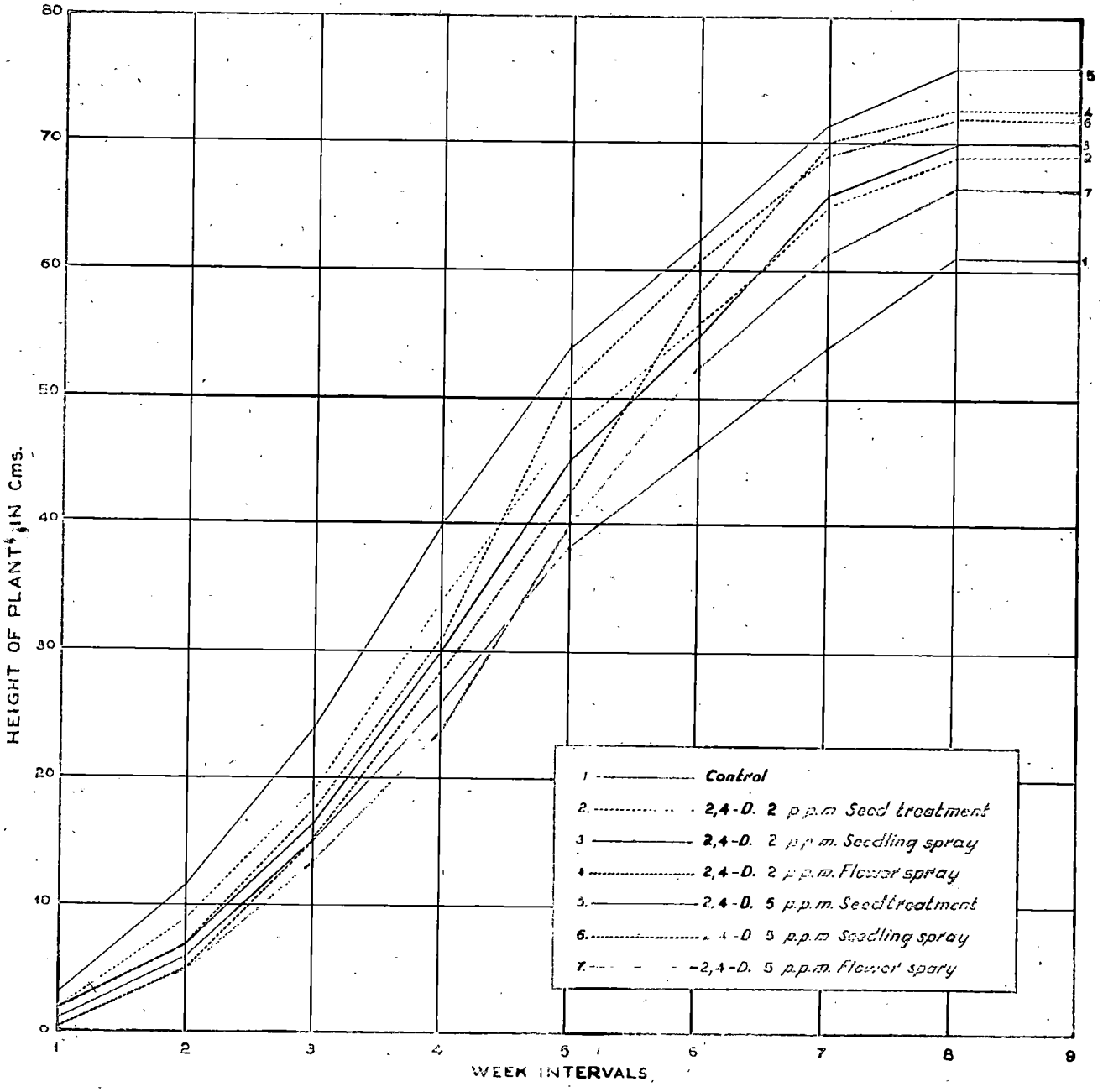

HEIGHT OF PLANT IN Cms.
WEEK INTERVALS
0
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
8
9
1 Control
2. 2,4-D. 2 p.p.m Seed treatment
3 2,4-D. 2 p.p.m. Seedling spray
4 2,4-D. 2 p.p.m. Flower spray
5. 2,4-D. 5 p.p.m. Seed treatment
6. 2,4-D 5 p.p.m Seedling spray
7. 2,4-D. 5 p.p.m. Flower spary

FIG. 3

FIGURE 4

Flower production and fruit-set

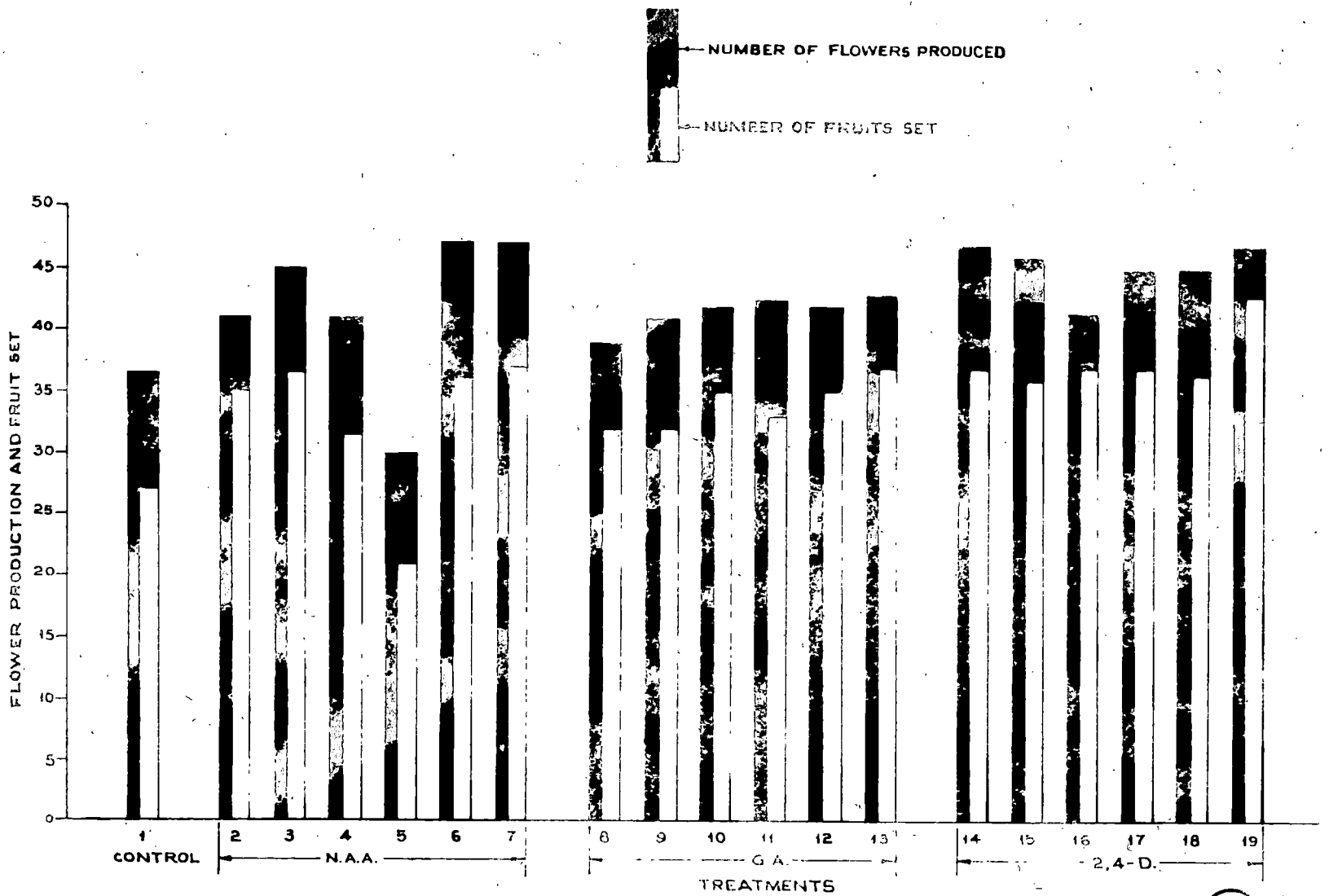

NUMBER OF FLOWERS PRODUCED
NUMBER OF FRUITS SET
FLOWER PRODUCTION AND FRUIT SET
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
CONTROL
N.A.A.
G.A.
2,4-D.
TREATMENTS

FIGURE 5

A. Weight of seeds in gms.

B. Oil content in percentage

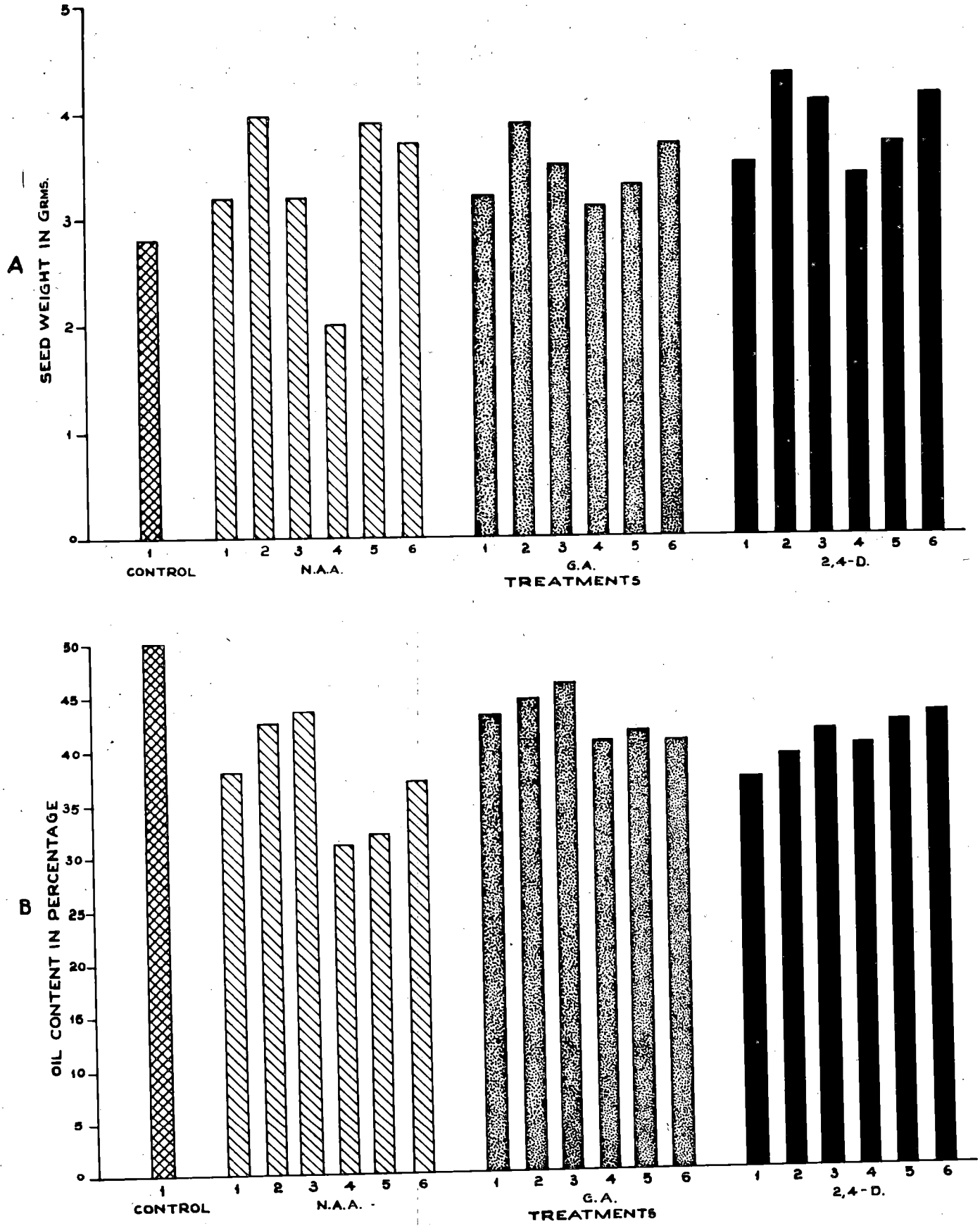
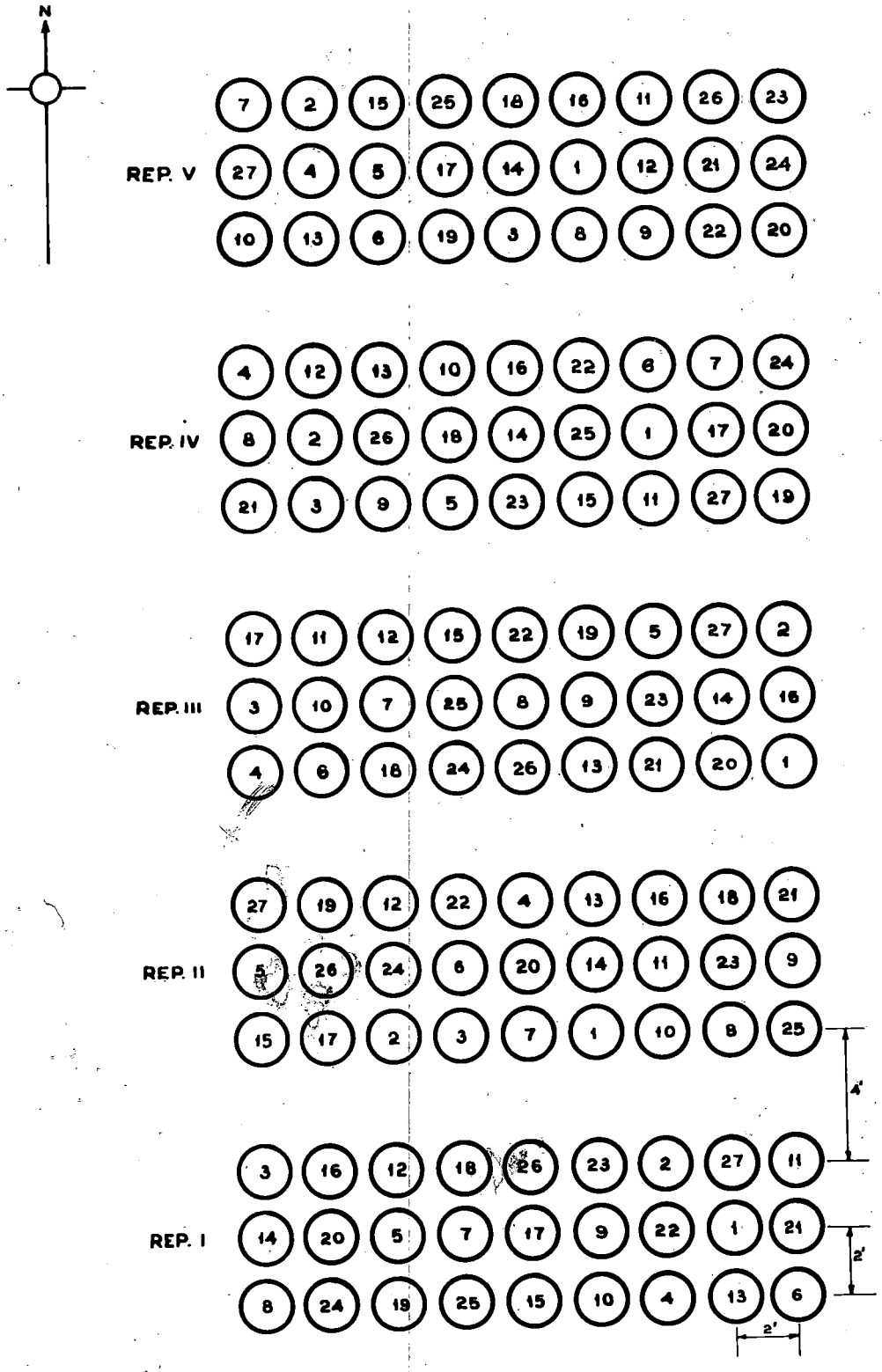

A
SEED WEIGHT IN GRMS.
0
1
2
3
4
5
1
CONTROL
1 2 3 4 5 6
N.A.A.
1 2 3 4 5 6
G.A.
1 2 3 4 5 6
2,4-D.
TREATMENTS
B
OIL CONTENT IN PERCENTAGE
0
5
10
15
20
25
30
35
40
45
50
1
CONTROL
1 2 3 4 5 6
N.A.A.
1 2 3 4 5 6
G.A.
1 2 3 4 5 6
2,4-D.
TREATMENTS

FIG. 5



PLAN OF LAYOUT OF THE EXPERIMENT

FIG. 6

PLATE I

Experimental plot

PLATE II

One block of the experimental plot


16

PLATE III

Comparison between treatment

19 - Control, 4- NAA 15 ppm.

Seed treatment

PLATE IV

Comparison between treatments

19 - Control, 7 - NAA 30 ppm.

Seed treatment


19
4

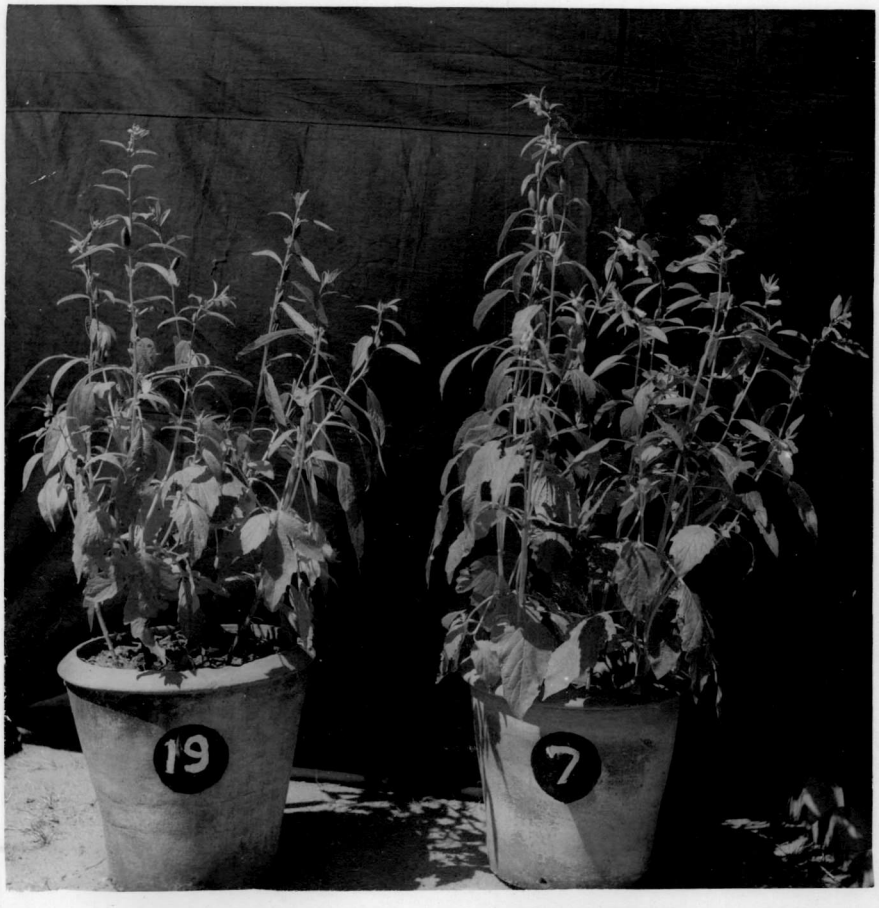

19
7

PLATE V

Comparison between treatments

20 - Control, 5 - NAA 15 ppm.

'Seedling spray'

PLATE VI

Comparison between treatments

20 - Control, 8 - NAA 30 ppm.

'flower spray'


20
5

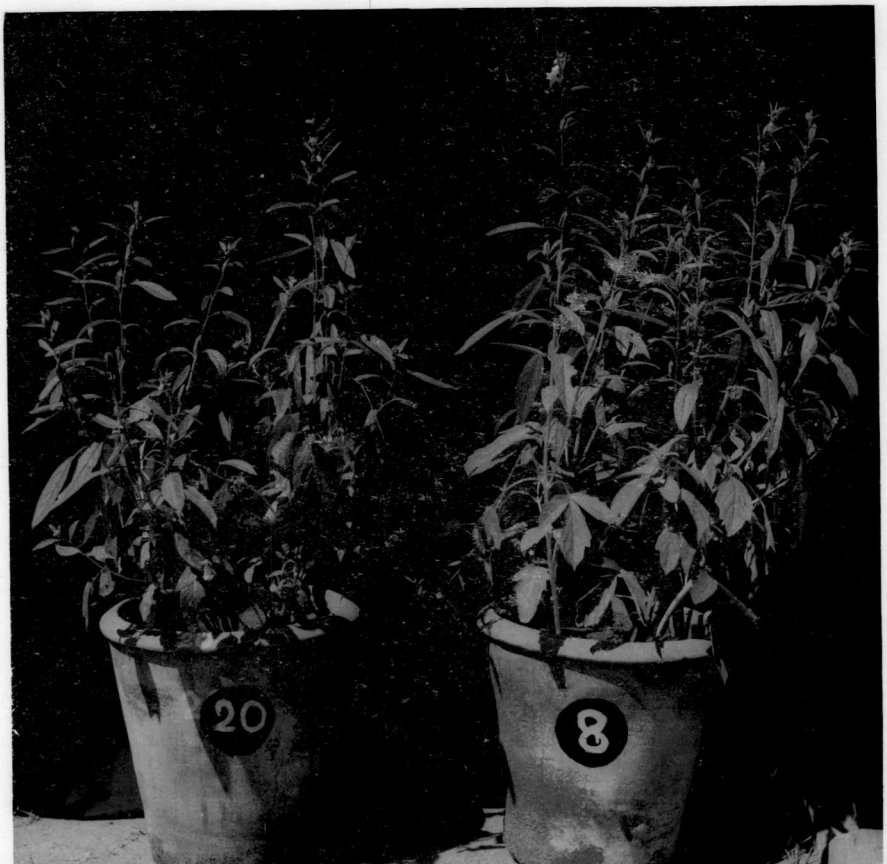

20
8

PLATE VII

Comparison between treatments

3 - Control, 6 - NAA 15 ppm.

'flower spray'

PLATE VIII

Comparison between treatments

3 - Control, 9 - NAA 30 ppm.

'flower spray'

PLATE VII

Comparison between treatments

3 - Control, 6 - NAA 15 ppm.

'flower spray'

PLATE VIII

Comparison between treatments

3 - Control, 9 - NAA 30 ppm.

'flower spray'


3
6


3

PLATE IX

Comparison between treatments
19 - Control, 13 - GA 25 ppm.
Seed treatment.

PLATE X

Comparison between treatments
19 - Control, 16 - GA 50 ppm.
'flower spray'


19
13


19
16

PLATE XI

Comparison between treatments

20 - Control, 14 - GA 25 ppm.

Seedling spray

PLATE XII

Comparison between treatments

20 - Control, 17 - GA 50 ppm.

Seedling spray


20
14


20

PLATE XIII

Comparison between treatments

3 - Control, 15 - GA 25 ppm.

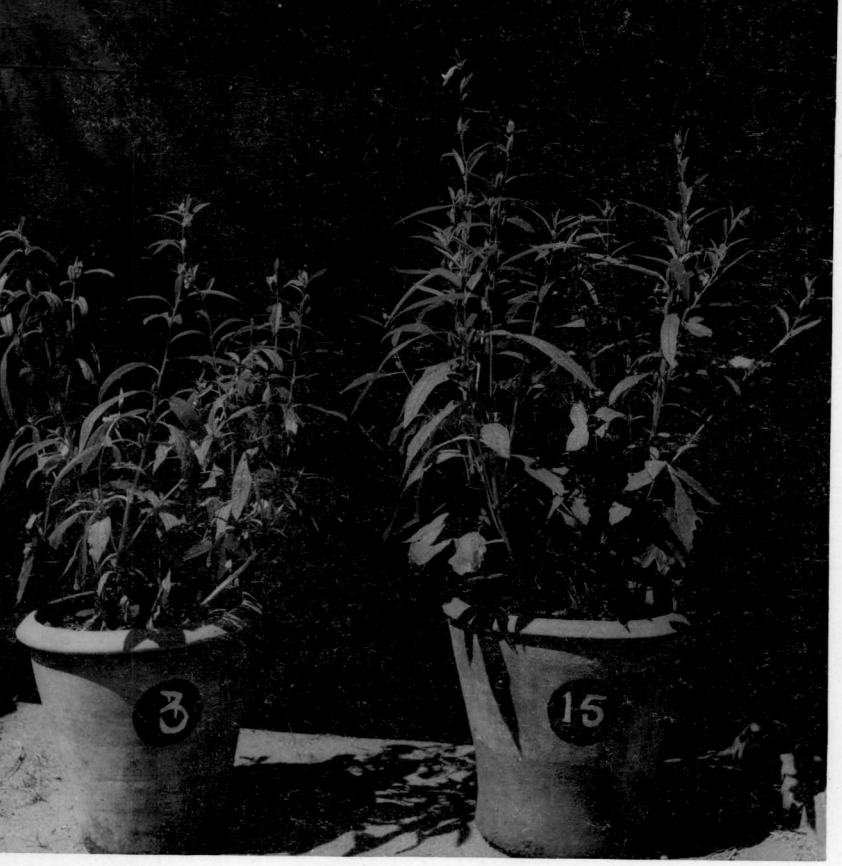
'flower spray'

PLATE XIV

Comparison between treatments

3 - Control, 18 - GA 50 ppm.

'flower spray'


3
15


3
18

PLATE XV

Comparison between treatments

19 - Control, 22 - 2, 4-D 2 ppm.

Seed treatment

PLATE XVI

Comparison between treatments

19 - Control, 25 - 2, 4-D 5 ppm.

Seed treatment


19
22


19
25

PLATE XVII

Comparison between treatments

20 - Control, 23 - 2, 4-D 2 ppm.

'seedling spray'

PLATE XVIII

Comparison between treatments

20 - Control, 26 - 2, 4-D 5 ppm.

seedling spray


20
23


20
26

PLATE XIX

Comparison between treatments

3 - Control, 24 - 2, 4-D 2 ppm.

'flower spray'

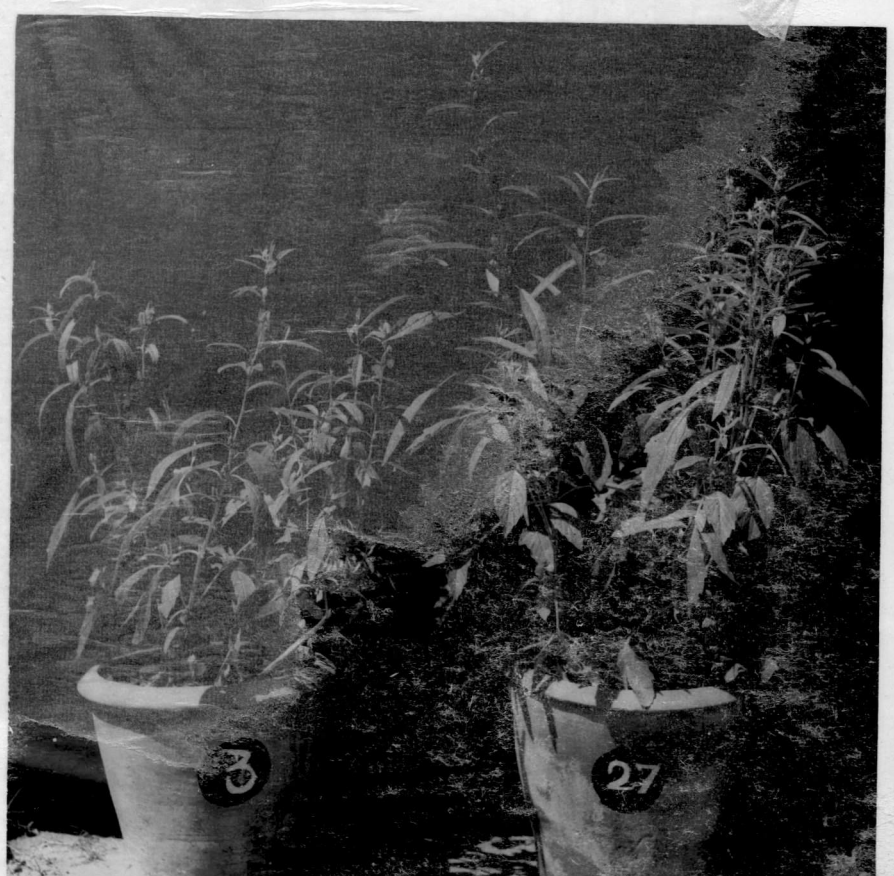
PLATE XX

Comparison between treatments

3 - Control, 27 - 2, 4-D 5 ppm.

'flower spray'


3
24


3
27