STANDARDISATION OF PROPAGATION TECHNIQUES IN BREAD FRUIT (*Artocarpus altilis* (Park.) Fosberg)

By

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THESIS
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D E C L A R A T I O N

I hereby declare that this thesis entitled "Standardisation of propagation techniques in bread fruit (*Artocarpus altilis* (Park.) Fosberg)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Jyothi

Vellayani
19.8.1986

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C E R T I F I C A T E

Certified that this thesis, entitled "Standardisation of propagation techniques in bread fruit (*Artocarpus altilis* (Park.) Fosberg)" is a record of research work done independently by Smt. Jyothi M.L., under my guidance and supervision and that it has not previously formed the basis for the award of any degree/ fellowship or associateship to her.

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INTRODUCTION

INTRODUCTION

Bread fruit (*Artocarpus altilis* (Park) Fosberg) is an important tree fruit vegetable grown in homesteads of Kerala. The crop is a native of Polynesia where it forms an important staple food. It is now grown throughout the humid tropical regions under well drained soils. In India its cultivation is now confined mainly to the southern states, cheifly on the West Coast. It can flourish in the drier parts of South India as well if well supplied with water and planted in fairly sheltered spots admist thick vegetation (Naik, 1949).

The tree possesses great economic value. The fruits are considered as a substitute for 'bread' and many tasty dishes are prepared out of it. The fruits of seedless bread fruit contain as high as 27.98 of per cent carbohydrate and is also a good source of calcium, vitamin A and vitamin B. The fibre from the bark and latex find use in industries. The tree is very handsome and can be grown as an ornamental tree in the garden (Singh *et al.*,1963).

Bread fruit has both seeded and seedless types, but the latter forms the economically viable ones. Hence bread fruit can be propagated only by vegetative means. This is usually achieved through root suckers. Suckers or shoots arise from the callus at the injured portions of the root. These are seperated and planted (Thomas, 1969). Cuttings taken from the roots are also used for the purpose. But the length and thickness of roots that give maximum success is not standardised under Kerala conditions. The influence of growth regulators on the performance of root cuttings is also yet to be investigated. Hence these aspects were taken up in the present investigation.

Unlimited removal of roots is harmful to the mother plant. It limits the wide use of this method in the propagation of bread fruit. Other methods of propagation which are less harmful to the mother plant include the use of stem cutting and layering. Propagation with stem cutting is easier and economical and may provide a large number of plants when compared to other vegetative methods. Bread fruit is generally considered as a difficult-to-root plant. The use of growth regulators is reported to enhance rooting in difficult-to-root plants. Hence the feasibility of this method with the use of growth regulators was also taken up for investigation.

Layering is another important method of vegetative propagation now being adopted in fruit plants. The principal advantage of layering over stem cutting is the success with which stems will develop roots. Many clones whose cuttings will not root can be propagated easily by layering. Use of growth regulators is found to aid rooting in layers. Application of growth regulators, particularly auxins is practised in many fruit plants for the same. The rooting potentiality is found to increase in young plants. Influence of season in the success of layering is also reported.

There are reports of success of these vegetative methods of propagation in many other fruit plants. However the work done in bread fruit on these aspects is scarce. A suitable method of propagation of this crop is not yet standardised for Kerala conditions where this crop finds a great acceptance and is widely used.

Hence this investigation was undertaken with the following objectives.

1. To standardise suitable methods for rapid multiplication of bread fruit by vegetative mean.
2. To find out the optimum length and thickness of roots and shoots for propagation.

3. To find out the optimum concentration of growth regulators for better rooting and establishment of the plants.

4. To study the effect of season on layering.

5. To study the rate of establishment of air layers in the nursery.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The review of literature relating to this study is given under the following titles. Since the references relating to bread fruit was not adequate studies on other related crops have been reviewed.

1. Propagation with root cuttings
2. Propagation with stem cuttings
3. Propagation through layering

In bread fruit, propagation through root cuttings and air layering is commercially practised, even though inarching, shield budding and the use of suckers is possible. (Mohammed, 1984).

1. Propagation with root cuttings

Plants that naturally produce suckers freely can be propagated easily by root cuttings. Certain species of plants that root rarely or not at all from stem cuttings can be reproduced by this methods.

Vegetative propagation of clonal material from root cuttings is receiving increased attention. Stoutemyer (1968) reported that over 150 species were known to have been successfully propagated in this way even by the middle of 19th century. Subsequently it has been recognised as a rapid, method to produce genetically identical material. Flemer (1961) reported that the difficulties in securing cuttings from the ground and the damage inflicted on stock plant make this method less frequently used. An important characteristic often associated with the use of root cutting is the restoration of more juvenile condition which has long been known to aid rooting.

1.1. Propagation techniques with root cutting

Root cuttings of about 2.5 cm diameter and 22 cm long, planted horizontally is generally recommended for bread fruit (Singh, 1980).

Julien (1945) described the method of propagating bread fruit trees. Cuttings from freshly dug roots, 8 inch long, and 3/10 to 1¼ inch in diameter were dipped in $KMnO_4$ (to coagulate the latex) and placed horizontally on sand bed and covered with a thin layer of sand ½ inch deep. After 45 days a large number of cuttings had developed tiny gall like protuberances, from which adventitious shoots were formed. A week after all cuttings bearing these structures have been grouped together and laid flat in the propagating bed with protuberances facing upward, covered with sand to a depth of ½ inch.

Otanes and Ruiz (1956) reported the results of trials with root cuttings of bread fruit. Root cuttings 15 cm long from hardwood materials (2.5 to 4.75 cms diameter) and semi hardwood materials (1.75 to 2.45 cm in diameter) gave 52 per cent, and 25 per cent success respectively, when planted at the beginning of rainy season in the open in 10-15 cm of river sand over lying dug soil. Planting during the dry season and the use of softwood and terminal root cuttings gave less satisfactory results.

Report of Lopez and Rodriguez (1975) showed that root cuttings of bread fruit, 12 inch in length produced sucker after several week under intermittent mist.

Some other fruit species propagated through root cuttings are Morus sp., Actinidia chinensis, Ficus carica, Malus sp., etc. (Hartman and Kester, 1978).

Regenerative ability of root cuttings depends on the age of the source plant. Garner and Hatcher (1958) concluded that 3-4 years period was the optimum age for sufficient number of vigorous root cuttings. In cherry plum, 58 per cent of root cuttings from 3 year old trees produced new roots compared to 2 per cent from 20 year old trees.

Turowskaya (1973) reported that root cuttings from 1 year old apple seedlings rooted better than those from 2-4 year old seedlings.

Research workers have utilized a wide range of diameter and length categories for the root cutting experiments. In 1935, Stoutemyer et al. reported that root cutting, 6 inch long and ½ to 1 inch in thickness, of apple var. Virginia Crab produced abundance of buds and shoots and attained a length of 6 inch in two months time. Comparative studies by Way et al. (1955) with apples showed that the establishment of independent plants from individual root segment dropped from 90 per cent with roots 18 cm long to 32 per cent with 5 cm long roots. A corresponding reduction in the vigour and shoot growth was recorded from shorter roots.

Studies with root cuttings of 3-5 year old plants of plum showed that cutting of 10-12 cm long and 3-15 mm diameter rooted best (Kurssakov and Kocanova, 1968). Stoilov (1980) who compared diameter differences with roots from 30 year old trees of wild apple (Malus sylvestris), found good regeneration on roots upto 1 cm, but a decreasing regenerative capacity with roots of larger diameter.

In a trial with root cuttings of Coffea canephora Ncumbu et al. (1982) found that 10 cm long cuttings from 5 year old trees, split and laid horizontally gave the highest number of shoots compared with 5 cm and 7.5 cm long cuttings. Studies with pecan root cuttings as reported by Bolt (1982) showed that root cuttings of length 100, 150 and 200 mm with an average diameter of 10-15 mm taken from 2 year old seedlings gave 60, 80 and 100 per cent rooting and 150, 200 and 250 mm stem length respectively after one year's growth.

Two year studies with 5, 10 and 15 cm long root cutting of Pyrus pashia showed that the best rooting (71-77 per cent was obtained with 15 cm long cuttings (Randhawa and Kishore, 1983).

Observationsmade from preliminary experiments on planting material and root diameter (ranging from less than 0.5 cm to more than 1 cm) in apple cv. Lambourne roots (Robinson and Schwabe, 1977) showed that roots in the size range from 0.5 - 1.5 cm gave reliable shoot production when planted horizontally. Shoot number and their lengths increased significantly with increased diameter. The percentage of roots producing one or more shoots in the three diameter classes (less than 0.5 cm, 0.5-1.0 cm, more than 1.0 cm) were 64 percent, 87 per cent and 78 per cent respectively. The longest root pieces used (16 cm) were more productive than shorter roots and only these could sustain the vigorous shoot growth.

The influence of depth of planting in the percentage of sprouting is reported by several authors. Stoutemyer *et al.* (1935) were unable to propagate Virginia Crab apple roots in the soil of a ground bed but achieved a high degree of success on the surface of moist sand. Light and/or aeration enhance the capacity for regeneration. Upshall (1936) and Way *et al.* (1955) reported an increase in root production from the distal end of the exposed root cutting and subsequently a better survival rate. Turovskaya (1965) found that although fewer shoots emerged from the exposed ends of root cuttings from one year old apple seedlings, their height was double that of shoots from covered roots, the leaf formation was more rapid. New root production on the original root cutting was also better, and survival was 100 per cent compared with 75 per cent for plants derived from covered roots. Heydecker and Marston (1967) used shallow horizontal planting (1.25 cm) with raspberry roots and found that deeper planting (4.0 cm) suppressed shoot growth.

1.2. Effect of growth regulators on root cuttings

The purpose of treating cuttings with auxins is to increase the percentage rooting, to hasten root initiation, to increase the number and quality of roots produced per cutting and to increase uniformity in rooting. The synthetic root promoting substances that have been found most reliable in stimulating adventitious root production in cuttings are in-dole butyric acid and naphthalene acetic acid (Hartman and Kester, 1978).

Work done by Plant, (1940) on the role of growth substances in the regeneration of root cutting show that roots were produced from all points of the root cutting of seakale when treated with a solution of 0.02 per cent NAA. He concluded that differentiation and behaviour of meristematic tissue is determined in part, by specific concentration of growth substances, a relatively high and low concentration of growth substance influences root and bud production respectively.

There are reports that roots generally have high IAA oxidase levels and correspondingly low levels of endogenous IAA. Avery et al. (1937) detected increasing levels of growth hormone in swelling buds with a peak just prior to the period of most rapid shoot extension.

According to Mitra and Allsopp (1959) 0.1 mg per litre NAA applied to protonemata of Pohlia nutans was sufficient to inhibit bud formation. Sterret and Chappel (1967) suggested that the initiation of buds on roots was more easily inhibited by auxin than the release of dormant stump buds. Root shoot formation was suppressed by IAA in lanolin paste applied on the cut surface of the suckers.

Experimental results on the effect of growth regulators on apple root cutting reported by Turovskaya (1977) showed that root cuttingstreated with solution of IBA at 50 mg per litre, IBA and a hereroauxin, HRV (petroleum based growth substance) at 0.02 per cent or 0.04 per cent had a beneficial effect on root development especially in cutting with previously induced shoot growth.

[1]Robinson and Schwabe (1977) reported that auxin (150 mg per litre) completely inhibited bud initiation along the whole length of cutting. Evidence that auxin caused a gradient by a mechanism of active acropetal flow was shown when proximal application of IBA suppressed all buds where as distal application did not interfere with bud formation at the proximal end.

In a trial with root cuttings of Coffea canephora, 10 cm long, split or entire cuttings were soaked (4-6 h) in IAA or NAA at 0.01 per cent or 0.015 percent. Alternatively, some split cuttings had one end dipped in IBA (4-6h) at 0.025 per cent. The results showed that the mortality of treated cuttings was 19-27 per cent compared with 8.6 per cent for water treated control. The percentage of cuttings that produced leafy shoots were 23.2 per cent for treated cuttings and 52.9 per cent for controls and the corresponding percentage for cuttings with shoots and roots were 18.4 per cent and 9.7 per cent NAA gave better rooting than IAA. IBA treatment for 6h caused high mortality (Nsumbu et al., 1982).

Use of growth substances other than auxin is also reported. Pieniazek and Saniewski (1970) applied an auxin and cytokinin seperately and in combination to entire apple root cuttings. 20 mg per litre NAA produced only roots and, 70 mg per litre 6-BAP caused only buds to form, where as 20 mg per litre and 10 mg per litre respectively produced only new roots. Warmke and Warmke (1950) found that treatment of Taraxacum and Cichorium root cuttings with vapours of the auxin inhibitor ethylene chlorhydrin caused buds to form at both ends.

1.3. Carbohydrates and regeneration from roots

In apple the importance of root bark for carbohydrate storage was shown by Priestly (1970). In such tissue 60 per cent of drymatter comprised extractable carbohydrate whereas in the tree as a whole 30 per cent of the drymatter comprised extractable carbohydrates. In the case of root cutting which have no source of carbohydrate replenishment, their detachment should obviously coincide with maximum accumulation of reserves.

Research workers have established relationship between carbohydrate content of root cuttings and their ability to produce suckers and survive. Early work by Upshall (1931) demonstrated that total carbohydrates in apple root cuttings decreased by 50 per cent after two weeks of regeneration, while reducing sugar and sucrose decreased upto 70 per cent. Mackenzi (1957) found a correlation between starch content in roots and their survival ability. The greatest concentration of starch occurred in November when regeneration was 100 per cent and cutting survived for several weeks. From May to September, starch content was very low and cuttings dried within a few days. Storrott *et al.* (1968) related the poor regeneration vigor of black locust root cutting in June to the low level of carbohydrates at that time.

Pieniazek and Saniewski (1968) postulated that cytokinins from roots stimulated starch hydrolysis and bud activation in Spring. Developing buds would then produce auxin which could continue the starch hydrolysis, increase respiration and reactivate vascular cambium.

Eliasson (1971) proposed that good regeneration from Populus root cutting in autumn was as a result of a combination of high carbohydrate and low auxin levels at that time.

Some relationship between seasonal regeneration capacity and carbohydrate content of roots was indicated in the case of M.26 and Lambourne varieties of apple, but ability to survive seemed to be more directly influenced by carbohydrate content than regenerative capacity. Cold storage treatment given to Lord Derby root cuttings accelerated regenerative responses without increasing total regenerative capacity[2] (Robinson and Schwabe, 1977).

2. Propagation with Stem cutting

In propagation by stem cuttings, segments of shoots containing a lateral or terminal bud are obtained with the expectation that under the proper conditions adventitious roots will develop and thus produce independent plant.

The type of wood, the stage of growth used in making cutting, the time of year in which the cuttings are taken and several other factors can be very important in securing satisfactory rooting of some plants. (Hartman and Kester 1978).

2.1 Effect of length and thickness of cutting on rooting

Branch cutting of tropical breadfruit of length 12-15 cm and 3-4 nodes and about 3/8 inch in diameter were found to root well (80 per cent success) when dipped in 1 per cent indole butyric acid solution (Muzik, 1948).

From the results of four years trials on the propagation by cuttings of 8 fig varieties, Ibragimov (1968) recommended that the best length was 25-30 cm, prepared in autumn from one year old shoots and stored for spring planting. Ammo, (1972) reported from the studies with 3 fig cultivars that rooting and subsequent plant development were better using cutting 30-40 cm. long and 1.1 to 1.5 cm in diameter than with cuttings 20 cm long and 0.8-1.0 cm in diameter. Out of the different lengths tried in fig cuttings, Pinheiro and Olivera (1973) reported that cuttings of length 20 cm and above gave more than 97 per cent success. The best root and leaf development was obtained with 35 cm and 30 cm. A minimum of 20 cm length is recommended.

Sampaio (1982) reported that soft wood cuttings of fig 10-15 cm long and with 3-4 leaves rooted under intermittent mist.

2.2 Effect of growth regulators on rooting of cuttings

Investigation as early in 1934 by Went, found that auxins such as IAA, were of real value in stimulating the production of adventitious roots in stem and leaf cuttings. This is an important information in vegetative propagation of plants. Of all the synthetic root promoting chemicals, IBA and NAA are the most widely used in stimulating adventitious root formation in cuttings.

Branch cuttings of the tropical bread fruit were found to root well when dipped in a 1% IBA solution (Muzik, 1948). Hamilton et al. (1983) reported that woody, leafless cuttings of the cvs Ma Opu and Maafula of bread fruit, when treated with 0.5% captan and 2500 ppm each of IBA and IAA and kept under intermittent mist effected in rooting of 95% of the cutting after 10 weeks.

In jackfruit, results on the trials with leafy and leafless cuttings dipped in IBA at 5000 and 10000 ppm solutions for 30 seconds showed that rooting percentage after 45 days was nil for all leafless cuttings, leafy cutting controls, and 90 and 60 per cent respectively for the 5000 and 10000 ppm

IBA treatment (Chatterjee and Mukherjee, 1980). The same authors in 1982 reported that the best rooting (100%) in jack-fruit was obtained with forced etiolated shoots treated with IBA at 5000 ppm by quick dip method.

Success with cuttings after ringing and etiolation of shoots for 30 days combined with IBA 3000 ppm + ferulic acid at 2000 ppm is reported in jack fruit by Dhua *et al.* (1983).

Singh *et al.* (1978) working on fig concluded that fig can be successfully propagated by the cuttings made from the pruned wood of January month with the aid of growth substance. Dipping of cutting in merculine 0.2 per cent was found most efficacious for the purpose. Highest percentage of rooting was obtained by Nunes *et al.* (1982) with semihard wood leafy cutting of fig when dipped in 600 and 1000 ppm IBA (90 and 79.4 per cent respectively vs. 55 per cent in control) and in non leafy cutting dipped in 400 ppm IBA (99.7 per cent vs. 77.2 per cent in control). Percentage of sprouting was highest in leafy cuttings dipped in 10000 ppm IBA (73.6 per cent vs. 61.8 per cent in control) and in non leafy cuttings dipped in 400 ppm IBA. (83.8 per cent on 65.15 per cent in control).

In *Ficus elastica* highest rooting percentage, number of primary roots per cutting, the greatest length of the largest primary root and best survival after transplanting were obtained with IBA at 4000 ppm (Kumar, 1982).

Chong *et al.* (1983) reported the use of IBA in improving the rooting of difficult to root species. Among the species *Saccharum* gave 45 per cent rooting with IBA at 5000 ppm, *Cotoneaster acutifolium*, *Taxus cuspidata* and *T. medica* cv. Hicksii gave 88, 71 and 68 per cent rooting with IBA at 20000 ppm respectively, and Malus cv. Hopa gave 71 per cent at 4000 ppm. No rooting was obtained with *Malus pumila* cv. Morspur, MC Intosh, *Philadelphus virginalis* cv. Weigela cv. Bristo Ruby.

3. Propagation through layering

Root formation during layering is stimulated by various stem treatment which cause an interruption in the downward translocation of organic materials such as carbohydrates, auxin and other growth factores. In many clones where cutting will not root easily can be propagated by layering, enabling the plant to be established on its own roots.

3.1 Juvenility as a factor in layering

Jack fruit is found to show clear signs of juvenility in seedlings. Results of study in air layering of jack fruit as reported by Srinivasan (1961) showed that young jack fruit plant which are still in the juvenile stage, give better rooting response compared to grown up plants. The trial gave 100 per cent success on two year plants with hard wood. Intermediate wood gave 96 per cent success where as green wood was found completely unsuitable showing no initiation of rooting.

3.2 Effect of growth regulators in layering

The effect of 1000, 5000 and 10,000 ppm of IAA, IBA, NAA and MH in lanolin applied at the time of ringing was studied in jack fruit. A significant increase was found in the percentage of layers rooting and the number of roots formed using the three growth regulators. IBA gave optimum results with 5000 ppm and IAA and NAA with 10,000 ppm. MH had an inhibiting effect on rooting. Layering in June was better than May. (Sen and Bose,1959). Lingarajappa (1982) from his studies on air layering in jack fruit reported that the percentage of layers which rooted successfully, the number of roots per layer, the length the weight of root and survival of the layers in the field were greater where stems were pregirdled, etiolated and treated with IBA + NAA than where any of these treatment was applied individually. Juvenile shoots formed roots 30 days earlier than mature shoots.

In mango, IBA at 5000 ppm was more effective than NAA in promoting the rooting and establishment of the marcots (Chhonkar and Singh, 1972). Chatterjee (1982) obtained 75 per cent rooting and 55 per cent plant survival in mango with IBA at 10000 ppm applied in lanolin paste. Applying IBA (2000 ppm) and NAA (5000 ppm) together, Patel and Singh (1982) obtained 66 per cent rooting in 25 year old trees of Langra var. of mango. Good rooting was obtained in the difficult-to-root cv. Langra by applying IBA at 15000 ppm to air layers (Rajan and Ram, 1983).

In cashew, Rajan *et al*. (1981) reported that good rooting and best field establishment (80 per cent) were obtained from layers treated with 300 ppm IBA + 200 ppm NAA + 10 ppm 2,4 - D.

3.3. Propagation through stooling

Stooling was investigated using 10 clones of one year old jack fruit plants. IBA 5000 ppm was applied in lanolin after removing a ring of bark. This method gave 75 per cent rooted shoots of which 71 per cent survived after one year (Chatterjee and Mukherjee, 1980).

Stooling and trench layering were compared in mango by Mukherjee and Majumder (1963). They found that in stooling mortality of the sprouts was negligible. The number of rooted shoots were significantly higher in stooling than layering. The rooting was more profuse in stooling than layering. The percentage of survival of rooted shoots was 93.8 per cent in stooling, whereas in layering it was 65 per cent.

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiment was carried out at the nursery of the Department of Horticulture, College of Agriculture, Vellayani during the period from September 1984 to December 1985.

The study consisted of three parts.

1. Propagation with root cuttings of bread fruit
2. Propagation with stem cuttings of bread fruit
3. Propagation through layering in bread fruit

The investigation envisaged the study of the effect of thickness and length of roots, thickness and length of shoots, the effect of growth regulator and also the nutritional status of the propagating material in relation to rooting and subsequent growth.

1. Propogation studies with root cuttings

1.1. Preparation of cuttings

Cuttings were made into three groups, based on thickness.

Thin cuttings	-	1-1.9 cms
Medium thick cuttings	-	2-2.9 cms
Thick cuttings	-	3-4 cms

The cuttings were further made into four groups under each thickness based on the length.

5 cm long, 10 cm long, 15 cm long and 20 cm long.

1.2. Growth regulators and their preparation

The two growth regulators IBA (Indole 3 - butyric acid) and NAA (Naphthaline acetic acid) were used at different concentrations.

Treatment with distilled water was taken as the control.

A stock solution of 1000 ppm IBA was prepared by dissolving 1 g of the chemical in a small quantity of 50 per cent ethanol and made up the volume to 1000 ml with distilled water. The stock solution was further diluted to the required concentrations and used for the study.

The same procedure was followed for the preparations of different concentrations of NAA.

1.3. Preparation of the nursery bed for rooting

The rooting medium consisted of sand and red earth at the proportion of 2:1. Wooden boxes 8" deep were made and were filled with the prepared soil mixture. Drainage facilities were provided at the bottom of the box. A thin layer (1") of sand was spread over the soil mixture after planting.

1.4 Treatments

Thickness (cm)	Length (cm)	Growth Regulators (ppm)	
		IBA	NAA
1 - 1.9	5	100	100
2 - 2.9	10	300	300
3 - 4	15	500	500
	20		

1.5. Experimental Design

The experiment was laid out in completely randomised design. The treatments comprised of the various possible combinations of the three levels of thickness, four lengths of cuttings and two growth regulators, IBA and NAA each at three concentrations. The control was kept common for both IBA and NAA treatments. Altogether there were 84 treatments.

Under each treatment a total of 10 cuttings were tested which was divided into 2 replications each consisted of 5 cuttings.

1.6. Treating the cuttings with growth regulators and planting

Cuttings of the same thickness and length were grouped together and made into bundles. Each such bundle consisted of 10 cuttings. The latex at the cut ends were wiped out with cotton. The growth regulators were taken in a small pan and the bundles of root cuttings were dipped in it. The cuttings were treated for a period of 12 hours. The control was given treatment with distilled water alone.

The cuttings were planted in the prepared medium with a portion of the root slightly exposed to sun. The treatments were distributed at random. The cuttings were irrigated by sprinkling water over it with a fine rose can. Watering was done very carefully not to over water and drench the soil. Continued irrigation resulted in the displacement of sand from above the root cuttings and the complete exposure of roots to sun. Such cuttings were again covered with sand.

The trays were arranged inside the greenhouse, where the entry of direct sun light is partially prevented.

1.7. Observations recorded

(i) Number of days for the appearance of first vegetative buds:

The number of days taken for the appearance of first green buds in the root cutting from the date of planting was counted.

(ii) Percentage of sprouting:

The number of cuttings sprouted under each treatment was counted and the percentage calculated.

(iii) Number of sprouts produced:

The number of vegetative buds produced in each of the root cutting were counted.

(iv) Number of days for leaf emergence:

Number of days taken for the emergence of leaves were recorded from the date of planting till 60 days after the appearance of the first vegetative bud.

(v) Plant height:

Height of plants were measured 6 months after planting.

(vi) Number of roots produced 60 days after sprouting:

Sixty days after sprouting, the plants were carefully lifted from the nursery bed, the roots were washed and the number of primary and secondary roots were recorded.

(vii) Length of roots:

The length of both primary and secondary roots were measured seperately.

They were then immediately planted in individual pots filled with potting mixture containing sand, soil and farmyard manure in the ratio 1:1:1.

(viii) Carbohydrate content in roots of different thickness:

Carbohydrate reserves of the roots were analysed using the anthrone method (Dubois et al. 1951).

Anthrone method

Root samples were digested with 20 per cent hydrochloric acid.

Stock solution of glucose

Stock solution of glucose was prepared by dissolving 1 g glucose in one litre of distilled water.

Standard glucose solution

Standard glucose solution of concentrations, 2, 4, 6, 8, 10 and 12 ppm were prepared by dissolving 2, 4, 6, 8, 10 and 12 ml of stock solution in 100 ml each of distilled water. Fresh anthrone reagent was prepared by dissolving 2 g of anthrone in one litre of concentrated sulphuric acid.

Aliquots of 1 ml of the extract was taken in a test tube. To each of it 4 ml of the anthrone reagent was added, allowing the reagent of run down the sides of the test tube. After keeping a glass marble on the top of each tube to prevent loss of water by evaporation, the tubes were placed in boiling water bath for 10 minutes. It was then removed and cooled to room temperature. A reagent blank was also treated simultaneously. The absorbance of the solution at 625 nm was measured. The amount of sugar present in the extract was calculated from a standard curve prepared from glucose.

1.8 Statistical analysis

The data were analysed as factorial CRD. The sum of squares due to the pertinant source of variations were worked out and the analysis of variance table prepared as per the method suggested by Snedecor and Cochran (1967). Critical difference was calculated in all cases where the effects were found to be statistically significant.

2. Propagation Studies with branch cutting

Cuttings were taken with a thickness of 2 to 2.9 cm and 3 to 4 cm. Under each thickness, cuttings of three length were made.

The cuttings were then treated with IBA at varying concentrations by quick dip method. All the cuttings were collected from the trees which were over 20 years old.

2.1. Preparation of the cuttings:

Terminal branch cuttings were used for the experiment. All the leaves except the terminal unopened ones were removed one week prior to collection of cuttings. The latex at the cut ends were wiped out at the time of making cuttings.

2.2 Preparation of the IBA solution

Weight of the chemical (g)	Dilution (ml)	Concentration of the solution (ppm)
0.5	100	5000
1.0	100	10000
1.5	100	15000

The required amount of IBA was first dissolved in a small quantity of 50 per cent ethanol and then made up the volume to 100 ml with distilled water.

2.3. Treatments

Thickness (cm)	Length (cm)	IBA (ppm)
2 - 2.9	15	5000
	25	10000
3 - 4	35	15000

The treatments comprised of the various possible combination of the levels of thickness, length and the different concentrations of IBA. There were 24 treatments in total.

2.4. Experimental design

The experiment was laid out in CRD with three replications under each treatment. Ten cuttings were used in each replication.

2.5. Preparation of rooting media

Trenches 60 cm wide, 45 cm deep and 3 m long were made and filled with sand and red soil mixture. These trenches were covered with thick transparent polythene sheet and sprayed water to the cuttings, frequently.

2.6. Treating with growth regulators and planting

Cuttings with uniform thickness and length were grouped into bundles of 30 each. The basal portion of the cuttings were dipped in the prepared IBA solution for a period of 5 seconds. Treatment with distilled water for the same duration was taken as the control.

The cuttings were then planted in the trenches allocating the different treatments at random. Planting was done during the first week of September 1985.

2.7. Observation recorded:

Observations were made on the number of cuttings that failed to establish at 10 and 20 days intervals and the percentage of success worked out.

3. Propagation Studies through layering

Layering was done in the selected shoots of both old (over 20 years) and in young juvenile plants (less than one year).

3.1. Layering in mature plants

Air layering was tried in two seasons (May-June and September-October). Layers were made on branches with different thickness: 2 to 2.9 cm and 3 to 4 cms.

3.1. (a) Preparation of growth regulators

The growth regulators such as IBA and NAA were used. Lanolin paste was used as the base for the use of growth regulator.

A stock of 10000 ppm was prepared by mixing 50 mg of the chemical in 5 g of lanolin paste. From the stock, further concentrations were prepared. The concentration of 15000 ppm of IBA and NAA were prepared by mixing 60 mg of the chemical in 4 g of lanolin. The lanolin was slightly melted and the chemical added, after which it is throughly mixed.

3.1. (b)

Concentration of the stock solution (ppm)	Dilution	Concentration obtained (ppm)
10000	200mg made upto 4g	500
10000	400mg made upto 4g	1000
10000	800mg made upto 4g	2000
10000	1200mg made upto 4g	3000
10000	1600mg made upto 4g	4000
10000	2000mg made upto 4g	5000

3.1. (c) Treatments

Thickness	Growth regulators	
	IBA (ppm)	NAA (ppm)
2 to 2.9 cm	500	500
	1000	1000
	2000	2000
3 to 4 cms	3000	3000
	4000	4000
	5000	5000
	10000	10000
	15000	15000

The different thickness and concentrations of the two growth regulators were given in the various possible combinations. Control was given with application of lanolin paste alone. There were 34 treatments altogether.

3.1. (d) Experimental Design

The experiment was laid out in completely randomised design. Three replications were assigned to each treatment and in each replications 10 shoots were layered.

3.1. (e) Preparation of rooting medium

Rooting medium was prepared by mixing sand and coconut pith at the ratio of 1:1. It was made wet by adding adequate amount of water.

3.1.(f) Layering

A ring of bark with 2 cm width was removed at a distance of 10-15 cm away from the tip of the stem. The growth regulators in lanolin was applied to the upper part of the girdled portions. The rooting medium was taken in polythene sheet of 250 guage and was wrapped around the girdled portion.

First layering was done in middle of October, '84 and the second in middle of June 1985.

3.1. (g) Observationsrecord

Observations were recorded on the number of layers rooted 4 months after layering.

3.2. Propagation through layering of young plants

One year old plants grown in pots were used for layering. The plants were of uniform size at the time of layering. Twenty plants were taken for the study.

The procedure of layering was the same as done in the case of mature shoots. No growth regulator treatment were given.

Observations recorded

1. Number of layers rooted
2. Days for the development of visual roots
3. Percentage of establishment of layers in the nursery

3.3. Propagation through stool layering

Five plants, three year old were taken for the experiment. They were headed back to a height of 20 cm from the ground. The cut end was treated with fungicide and covered with a cap. Sprouts were allowed to develop. When the shoots were about 30 cm long and brown at the base, layering was done. Three shoots were selected from each plant. A ring of bark was removed 15 cm away from the tip. IBA at 1000 ppm was applied at the upper end of the girdled portion. Soil was heaped at the base. Frequent irrigation was given to keep the soil always in moist condition. Soil washed away during irrigation was frequently replaced.

Observations recorded:

After 45 days of layering the soil was removed and the number of rooted shoots were recorded.

RESULTS

RESULTS

The observations made in the present study were statistically analysed and the results obtained are presented under the following titles.

1. Propagation with root cuttings
2. Propagation with stem cuttings
3. Propagation through layering

1. Propagation with root cuttings

Root cuttings with a length of 5 cm and 10 cm and those treated with IBA 500 ppm and NAA 500 ppm did not give any satisfactory results. Hence the data from these treatments were not used for statistical analysis. The data from the remaining thirty treatments were statistically analysed and the results interpreted.

1.1 Effect of treatments on the days taken for sprouting

The effect of treatments on the number of days taken for sprouting was statistically significant. (Appendix - I). Untreated thin roots of 15 cm length showed the earliest sprouting (43 days) which was followed by thin roots of 20 cm length treated with NAA at 100 ppm (43.5 days). The difference between these two treatments was not statistically significant.

Medium thick root cuttings of length 15 cm treated with IBA 300 ppm recorded the maximum delay in sprouting (138-5 days) (Table 1).

Thin root cuttings in general recorded lesser number of days for sprouting. Longer cuttings were earlier in sprouting. Average number of days taken for sprouting was significantly lesser in water treated controls except that in NAA 100 ppm treated cuttings. The lower concentration of IBA and NAA were found to be superior to their higher concentrations with regard to the character studied (Fig. 1).

Significant interaction effects were also observed among the different combination of factors. Untreated thin cuttings was found to produce earlier sprouting which was followed by thin cuttings treated with NAA 100 ppm. Treatments with water and NAA at both concentrations resulted in earlier sprouting in thin root cuttings, whereas IBA at both concentrations recorded earlier sprouting when treated to thick root cuttings. Longer roots recorded significantly lesser number of days for sprouting when treated with growth regulators, but in control, shorter roots were found promising. Longer roots treated with NAA 100 ppm and untreated shorter roots were earlier in sprouting. Long cuttings recorded earlier sprouting with thin and thick roots while the shorter

Table 1. Effect of treatment combinations on the number of days taken for sprouting

Thickness (cm)	Length (cm)	Growth regulators (ppm)				
		IBA 100	IBA 300	NAA 100	NAA 300	Control
1 to 1.9	15	118.5	128	66	74	43
	20	114.5	111	43.5	52	43.5
2 to 2.9	15	71.5	138.5	61.5	70.5	64
	20	92	124.5	68.5	75	76.5
3 to 4	15	79.5	90.5	85.5	103.5	70
	20	62.5	84	68.5	82.5	71.5

$S.E._m$ = 1.62

C.D. (0.05) = 4.68

Table 2. Main effects and interaction effects on the number of days taken for sprouting

Thickness (cm)	Growth regulators (ppm)					
	IBA 100	IBA 300	NAA 100	NAA 300	Control	Mean (Thickness)
1 to 1.9	116.5	119.5	54.8	63	45.8	79.9
2 to 2.9	81.8	131.5	65	72.8	71.3	84.5
3 to 4	71	87.3	77	93	74.8	80.6
Length (cm)						Mean (Length)
15	89.8	119	71	82.7	61.7	84.8
20	89.7	106.5	60.2	69.8	66.2	78.5
Mean (Growth regulators)	89.8	112.8	65.6	76.3	63.9	

Length (cm)	Thickness (cm)		
	1 to 1.9	2 to 2.9	3 to 4
15	85.9	81.2	87.4
20	73.9	87.7	73.8

C.D. (0.05)

Thickness - 1.5, Length - 1.2, Growth regulators - 1.9

Thickness x Growth regulator - 3.34

Length x Growth regulator - 2.70

Thickness x Length - 2.1

cuttings produced earlier sprouting in roots of medium thickness. However thin and thick roots of higher length recorded comparitively lesser number of days for sprouting (Table 2).

1.2 Effect of treatments on the percentage of sprouting

Significant difference was noticed between the effects of treatments on the percentage of success in sprouting (Appendix - II).

The percentage of sprouting recorded was maximum for the following four treatments combinations.

Thickness: 3 to 4 cm, Length: 20 cm and no growth regulator treatment

Thickness: 2 to 2.9 cm, Length: 20 cm and no growth regulator treatment

Thickness: 2 to 2.9 cm, Length: 20 cm, Growth regulator: NAA 100 ppm

Thickness: 2 to 2.9 cm, Length: 15 cm, Growth regulator: NAA 100 ppm

The percentage of sprouting recorded was minimum for the following three treatment combinations.

Thickness: 1 to 1.9 cm, Length: 15 cm, Growth regulator: IBA 300 ppm

Thickness: 1 to 1.9 cm, Length: 20 cm, Growth regulator: NAA 100 ppm

Thickness: 2 to 2.9 cm, Length: 15 cm, Growth regulator: IBA 100 ppm (Table 3)

Data showed an overall increase in the percentage of sprouting with an increase in the thickness and length of cuttings. Thin cuttings were found to be inferior to the cuttings with medium thickness and thick cuttings. The difference between medium thick and thick cuttings was not statistically significant. Higher concentrations of growth regulators reduced the percentage of success in sprouting. Percentage of sprouting was significantly higher in water treated control when compared to that in different growth regulator treatments except in NAA 100 ppm treatment (Table 4) (Fig. 3).

NAA 100 ppm applied to medium thick cuttings was found to be significantly superior to most of the treatments. However it was on par with thick cuttings treated with IBA 100 ppm and NAA 100 ppm and untreated thick cuttings. Further, the effect of growth regulators was not the same for different thickness of the cuttings. IBA at both concentrations produced better results with thick cuttings, whereas NAA produced higher success in sprouting with medium thick cuttings.

Longer cuttings recorded more success in sprouting when treated with growth regulators.

Table 3. Effect of treatment combinations on the percentage of sprouting

Thickness (cm)	Length (cm)	Growth regulators (ppm)				
		IBA 100	IBA 300	NAA 100	NAA 300	Control
1 to 1.9	15	39.22	26.55	32.89	32.89	39.22
	20	44.98	32.89	26.55	44.98	44.98
2 to 2.9	15	26.55	39.22	57.08	39.22	39.22
	20	39.22	39.22	57.08	50.75	57.08
3 to 4	15	50.75	44.98	50.75	39.22	50.75
	20	50.75	39.22	50.75	39.22	57.08

$S.E_m$: 3.71

C.D.(0.05) : 10.72

Data given are the transformed values.

Table 4. Main effects and interaction effects on the percentage of sprouting

Thickness (cm)	Growth regulators (ppm)					
	IBA 100	IBA 300	NAA 100	NAA 300	Control	Mean (Thickness)
1 to 1.9	42.10	29.72	29.72	38.93	42.10	36.51
2 to 2.9	32.89	39.22	57.08	44.98	48.18	44.40
3 to 4	50.75	42.10	50.75	39.22	53.91	47.34
Length (cm)						Mean (Length)
15	38.84	36.92	46.90	37.11	43.06	40.57
20	44.98	37.11	44.79	44.98	53.05	44.98
Mean (Growth regulators)	41.91	37.01	45.85	41.04	48.05	

Length (cm)	Thickness (cm)		
	1 to 1.9	2 to 2.9	3 to 4
15	34.15	40.26	47.29
20	38.88	48.67	47.4

C.D. (0.05)

Thickness - 3.39; Length - 2.77
Growth regulators - 4.38; Thickness x Growth regulator - 7.58
Length x Growth regulators - 6.19;

Data given are the transformed values.

However untreated long cuttings recorded higher percentage of sprouting compared to other treatments. The interaction effect between thickness and length of cuttings was not significant (Table 4).

1.3 Effect of treatments on the number of sprouts per cutting

The effect of treatments was significant with regard to the number of sprouts produced per cutting (Appendix - III).

Maximum number of sprouts per cutting was recorded in untreated thick roots of length 20 cm. Statistically this treatment was on par with the following treatment combinations.

Thickness: 3 to 4 cm, Length: 20 cm, Growth regulators: IBA 100 ppm

Thickness: 3 to 4 cm, Length: 20 cm, Growth regulators: NAA 100 ppm

Thickness: 3 to 4 cm, Length: 20 cm, Growth regulators: NAA 300 ppm

Thickness: 3 to 4 cm, Length: 15 cm, Growth regulators: NAA 300 ppm

Thickness: 2 to 2.9 cm, Length: 15 cm, Growth regulators: NAA 100 ppm (Table 5).

Thick roots in general produced significantly higher number of sprouts than medium thick and thin root cuttings. Longer cuttings were better than shorter cuttings in the number of sprouts per cutting. Growth regulators did not show any significant influence in the character studied. However the interaction between the effect of thickness and growth regulators was significant.

Increased thickness of cutting had a beneficial effect on the number of sprouts per cutting except in the case of treatment with IBA 300 ppm for which the differences was not significant. Untreated thick cuttings and thick cuttings treated with NAA 300 ppm recorded higher number of sprouts per cutting. There was positive interaction between the effects of length and thickness of cuttings. Long and thick cuttings were found to be significantly superior to all others. Length of cuttings had a significant positive effect only with regard to thick cuttings. In the other two type of cuttings, length failed to show any significant effect on the number of sprouts produced. The interaction between the effect of length and growth regulators was not significant (Table 6).

Table 5. Effect of treatment combinations on the number of sprouts per cutting

Thickness (cm)	Length (cm)	Growth regulator (ppm)				
		IBA 100	IBA 300	NAA 100	NAA 300	Control
1 to 1.9	15	1.57	1.41	1.41	1.41	1.41
	20	1.41	1.57	1.41	1.57	1.41
2 to 2.9	15	1.41	1.41	1.73	1.41	1.41
	20	1.41	1.41	1.41	1.41	1.57
3 to 4	15	1.41	1.41	1.41	1.73	1.57
	20	1.73	1.41	1.73	1.73	1.87

$S.E_m$ = 0.07

C.D. (0.05) = 0.20

Data given are the transformed values.

Table 6. Main effects and interaction effects on the number of sprouts per cutting

Thickness (cm)	IBA 100	IBA 300	NAA 100	NAA 300	Control	Mean (Thickness)
	Growth regulator (ppm)					
1 to 1.9	1.49	1.49	1.41	1.49	1.41	1.46
2 to 2.9	1.41	1.41	1.57	1.41	1.49	1.46
3 to 4	1.57	1.41	1.57	1.73	1.72	1.6
Length (cm)						Mean (Length)
15	1.47	1.41	1.52	1.52	1.47	1.48
20	1.52	1.47	1.52	1.57	1.62	1.54
Mean (Growth regulator)	1.49	1.44	1.52	1.55	1.54	

Length (cm)	Thickness (cm) 1 to 1.9	2 to 2.9	3 to 4
15	1.45	1.48	1.51
20	1.48	1.45	1.70

C.D (0.05)

Thickness - 0.06;
Length - 0.05
Thickness x Growth regulators - 0.14
Thickness x Length - 0.09

Data given are the transformed values.

4.4 Effect of treatments on the days taken for leaf emergence

The mean values of the observations are presented in the tables from 7 to 12.

The effect of treatments on the number of days taken for leaf emergence was significant. (Appendix - IV). The time taken for the emergence of all the six leaves was noticed to be earlier from thin roots of length 20 cm treated with NAA 100 ppm. Medium thick roots of length 15 cm treated with IBA 300 ppm recorded the maximum number of days for leaf emergence.

The main effects of treatments when compared, gave the following results.

Medium thick roots recorded more number of days for leaf emergence than the thin and thick roots. The longer roots were earlier in leaf emergence than the shorter roots. Higher concentrations of IBA and NAA delayed leaf emergence than their respective lower concentrations. Earlier emergence of the first leaf was noticed from water treated controls. It was on par with NAA 100 ppm treatment for the emergence of subsequent leaves.

The interaction effects among thickness, length and growth regulator application was significant. Increase in

Table 7. Effect of treatment combinations on the days for first and second leaf emergence

Thickness (cm)	Length (cm)	Growth regulators (ppm)									
		IBA 100		IBA 300		NAA 100		NAA 300		Control	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1 to 1.9	15	124.5	132.5	139.5	147.5	74	82	83	91.5	53	59.5
	20	118.5	126.5	122	130.5	52	55.5	71	83	54	64.5
2 to 2.9	15	76.5	88.5	147	156	68	75.5	77.5	85.5	73.5	85
	20	102.5	111.5	135	142	77	84	83	89.5	82.5	88.5
3 to 4	15	85	91.5	101	108.5	93	99	113	119	86	93.5
	20	67.5	73	91	105	77	84.5	87.5	97.5	78.5	86.5

First Leaf

$S.E._m$ - 1.5

$C.D_{(0.05)}$ 4.2

Second Leaf

$S.E._m$ - 1.6

$C.D_{(0.05)}$ 4.6

Table 8. Effect of treatment combinations on the days for third and fourth leaf emergence

Thickness (cm)	Length (cm)	Growth regulators (ppm)									
		IBA 100		IBA 300		NAA 100		NAA 200		Control	
		3rd	4th	3rd	4th	3rd	4th	3rd	4th	3rd	4th
1 to 1.9	15	141.5	149	159.5	167	94	101	107.5	119.5	76.5	86
	20	134	143	141	145.5	70.5	75	93.5	104.5	75.5	83
2 to 2.9	15	109	120	172.5	181	89.5	104	99.5	115.5	102	113
	20	117.5	124.5	159.5	168	95.5	103	101.5	108.5	99.9	107.5
3 to 4	15	103.5	110.5	118.5	126	111.5	118.5	133	141.5	106	113.5
	20	96.5	102.5	121.5	134.5	98	106	109	127	99	106

<u>Third Leaf</u>

$S.E._m$: 1.7

C.D.(0.05) : 5.0

<u>Fourth Leaf</u>

$S.E._m$: 1.6

C.D.(0.05) : 4.7

Table 9. Effect of treatment combinations on the days taken for fifth and sixth leaf emergence

Thick-Ness(cm)	Length (cm)	Growth regulators (ppm)									
		IBA 100		IBA 300		NAA 100		NAA 300		Control	
		5th	6th	5th	6th	5th	6th	5th	6th	5th	6th
1 to 1.9	15	162.5	176.5	182.5	190.5	114	122.5	131	139	105	112
	20	156.5	164	158	168	82	92.5	111	122.5	94	104
2 to 2.9	15	133.5	139.5	196	201.5	120.5	127.5	124	135	125	136
	20	136.5	144	181	190.5	117	124.5	122	132.5	119.5	126.5
3 to 4	15	123.5	131	138.5	147	133	142.5	154.5	161	128	135
	20	121	130.5	139.5	151	117.5	123.5	139.5	152	117	124

<u>Fifth Leaf</u>

S.E.m : 1.7

C.D. (0.05) : 4.8

<u>Sixth Leaf</u>

S.E.m : 1.9

C.D. (0.05) : 5.60

Table 10. Main effects and interaction effects on the days taken for first and second leaf emergence

Thickness (cm)	Growth regulators (ppm)											
	IBA 100		IBA 300		NAA 100		NAA 300		Control		Mean (Thickness)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1 to 1.9	121.5	129.5	130.8	139.0	63.0	68.8	77.0	87.3	53.5	62	89.2	97.3
2 to 2.9	89.5	100.0	141.0	149.0	72.5	79.8	80.3	87.0	78.0	86.8	92.3	100.5
3 to 4	76.3	82.3	96.0	106.8	85.0	91.8	100.3	108.3	82.3	90	88.0	95.8
Length (cm)											Mean (Length)	
15	95.3	104.2	129.2	137.3	78.3	85.5	91.2	98.7	70.8	79.3	93.0	101
20	96.2	103.7	116.0	125.8	68.7	74.7	80.5	89.7	71.7	79.8	86.6	94.7
Mean (Growth regulators)	95.8	103.9	122.6	131.6	73.5	80.1	85.8	94.2	71.3	79.6		

Length (cm)	Thickness (cm)					
	1 to 1.9		2 to 2.9		3 to 4	
	1st	2nd	1st	2nd	1st	2nd
15	94.8	102.6	88.5	98.1	95.6	102.3
20	83.5	92	96	102.9	80.3	89.3

C.D. (0.05) (First Leaf)

Thickness : 1.3, Length : 1.1, Growth regulators: 1.7
Thickness x Growth regulators : 3.0,
Length x Growth regulators : 2.5
Thickness x Length : 2.1

C.D. (0.05) (Second leaf)

Thickness: 1.5, Length: 1.2,
Growth regulators: 1.9
Thickness x Growth regulators: 3.3
Length x Growth regulators : 2.7
Thickness x Length : 2.1

Table 11. Main effects and interaction effects on the days taken for third and fourth leaf emergence

Thickness (cm)	Growth regulator (ppm)										Mean (Thickness)	
	IBA 100		IBA 300		NAA 100		NAA 300		Control			
	3rd	4th	3rd	4th	3rd	4th	3rd	4th	3rd	4th	3rd	4th
1 to 1.9	137.0	146	150.3	156.3	82.3	88	100.5	112	76	84.5	109.4	117.4
2 to 2.9	113.3	122.3	166	174.5	92.5	103.5	100.5	112	100.8	110.3	114.6	124.5
3 to 4	100	106.5	120	130.3	104.75	112.3	121	134.3	102.5	109.8	109.7	118.6
Length (cm)											Mean (Length)	
15	118	126.5	150.2	158	98.3	107.8	113.3	125.5	94.8	104.2	114.9	124.4
20	116	123.3	140.7	149.3	88	94.7	101.3	113.3	91.3	98.8	107.5	115.9
Mean (Growth regulators)	117	124.9	145.4	153.7	93.2	101.3	107.3	119.4	93.1	101.5		

Length (cm)	Thickness (cm)					
	1 to 1.9		2. to 2.9		3 to 4	
	3rd	4th	3rd	4th	3rd	4th
15	115.8	124.5	114.5	126.7	114.5	122
20	102.9	110.2	114.7	122.3	104.8	115.2

C.D. (0.05) (Third Leaf)

Thickness : 1.6, Length: 1.3, Growth regulators: 2.1
Thickness x Growth regulators : 3.6
Length x Growth regulators : 2.9
Thickness x Length : 2.3

C.D. (0.05) (Fourth Leaf)

Thickness: 1.5, Length: 1.2,
Growth regulators: 1.9
Thickness x Growth regulators : 3.3
Length x Growth regulators : 2.7
Thickness x Length : 2.1

Table 12; Main effects and interaction effects on the days taken for fifth and sixth, leaf emergence

Thickness (cm)	Growth regulators (ppm)											
	IBA 100		IBA 300		NAA 100		NAA 300		Control		Mean (Thickness)	
	5th	6th	5th	6th	5th	6th	5th	6th	5th	6th	5th	6th
1 to 1.9	159.5	170.3	170.3	179.3	98.0	107.5	121.0	130.8	99.5	108.0	129.7	139.2
2 to 2.9	135	141.8	188.5	196.0	118.8	126.0	123.0	133.8	122.3	131.3	137.5	145.8
3 to 4	122.3	130.8	139.0	149.0	125.3	133.0	147.0	156.5	122.5	130.0	131.2	139.9
Length (cm)											Mean (Length)	
15	139.8	149.0	172.3	180.0	122.5	130.8	136.5	145.0	119.3	128.0	138.1	146.5
20	138	146.2	159.5	169.8	105.5	113.5	124.2	135.7	110.2	118.2	127.5	136.7
Mean (Growth regulators)	138.9	147.6	165.9	174.8	114.0	122.2	130.3	140.3	114.8	123.1		

Thickness (cm)	Thickness (cm)					
	1 to 1.9		2 to 2.9		3 to 4	
	5th	6th	5th	6th	5th	6th
15	139	148.1	139.8	147.9	135.5	143.5
20	120.3	130.2	135.2	143.6	126.9	136.2

C.D. (0.05) (Fifth Leaf)

Thickness: 1.5, Length: 1.2, Growth regulators: 2.0
Thickness x Growth regulators: 3.4
Length x Growth regulators: 2.8
Thickness x Length : 2.1

C.D. (0.05) (Sixth Leaf)

Thickness: 1.8, Length: 1.5
Growth regulators: 2.3
Thickness x Growth regulators: 4.0
Length x Growth regulators: 3.2
Thickness x Length : 2.5

thickness increased the time taken for leaf emergence in the case of roots treated with NAA and in water treated controls. However in treatments with IBA, thick roots recorded lesser number of days for leaf emergence.

Increasing the length of cuttings reduced the time taken for leaf emergence when treated with growth regulators. Water treated thin cuttings and longer cuttings treated with NAA at 100 ppm recorded lesser number of days for leaf emergence than other treatments. First and second leaf emergence was earlier from thick and long cuttings, but the emergence of subsequent leaves was earlier from thin and long cuttings. In all the three levels of thickness tried, increasing the length of cutting was found to reduce the number of days for leaf emergence.

1.5 Effect of treatments on the height of plants

The mean values of height of the plants are presented in table 13 and 14.

Significant differences were observed between the different treatments on the character studied (Appendix - V). Maximum height of 42.5 cm was recorded from thin root cuttings of length 20 cm treated with NAA 100 ppm which was on par with untreated thin cuttings of length 15 cm (41 cm). Thin cuttings of length 15 cm treated with IBA at a concentration of 300 ppm recorded the minimum height (9.75 cm).

It was observed from the data that thin cuttings produced taller plants. The differences among cuttings belonging to the three thickness groups were statistically significant. Increasing the length of cuttings resulted in the increased height of plants (Plate-1). Growth regulators at higher concentrations reduced the height of plants (Plate-2). Plants from untreated cuttings were significantly taller and they were followed by those treated with NAA 100 ppm. Cuttings treated with IBA 300 ppm produced the shortest plants (Fig. 2).

Interaction effects among the different combination of factors were significant. Thin root cuttings produced taller plants when treated with water and with NAA at 100 and 300 ppm, whereas thick roots produced taller plants when treated with IBA at both concentrations. However thin roots treated with water were found to produce plants recording the maximum height. Increasing the length of cuttings had a beneficial effect in cuttings treated with water and NAA. But no significant difference was noticed between cuttings of

Table 13. Effect of thetreatment combinations on the height of plant (cm)

Thickness (cm)	Length (cm)	Growth regulators (ppm)				
		IBA 100	IBA 300	NAA 100	NAA 300	Control
1 to 1.9	15	12.75	9.75	28.55	21.75	41
	20	12	11.75	42.5	31.25	39.25
2 to 2.9	15	16.5	10.75	31.9	19.5	21.05
	20	15.25	10.95	20.8	21.65	21.5
3 to 4	15	22	20.5	22.6	18	27.3
	20	23.5	19.25	26.45	23.7	32.6

$S.E._m$ = 0.59

$C.D_{(0.05)}$ = 1.71

Table 14. Main effects and interaction effects on the height of plants (cm)

Thickness (cm)	Growth regulators (ppm)					
	IBA 100	IBA 300	NAA 100	NAA 300	Control	Mean (Thickness)
1 to 1.9	12.38	10.75	35.53	26.5	40.13	25.06
2 to 2.9	15.88	10.85	26.35	20.58	21.28	18.99
3 to 4	22.75	19.88	24.53	20.85	30.45	23.69
Length (cm)						Mean (Length)
15	17.08	13.67	27.68	19.75	29.75	21.59
20	16.92	13.98	29.92	25.53	31.45	23.56
Mean (Growth regulators)	17	13.83	28.8	22.64	30.62	

Length (cm)	Thickness (cm)		
	1 to 1.9	2 to 2.9	3 to 4
15	22.76	19.94	22.08
20	27.35	18.03	25.3

C.D. (0.05)

Thickness - 0.54, Length - 0.44
Growth regulators - 0.70,
(Thickness x Growth regulators) - 1.21
(Length x Growth regulators) - 0.99
(Thickness x Length) - 0.77

Plate 1. Effect of length of root cuttings on plant height

1. 15 cm
2. 20 cm

Plate 2. Effect of growth regulators on plant height

1. IBA 100 ppm
2. IBA 300 ppm
3. NAA 100 ppm
4. NAA 300 ppm

plate-1 (x0.15)

plate-2 (x 0.1)

the two different lengths when treated with IBA at both concentrations. Untreated long cuttings produced the tallest plants.

Cuttings of the two different lengths under the same thickness varied significantly on the character studied except with medium thick cuttings. In thin and thick cuttings, increasing the length of cuttings resulted in increased height of plants. Taller plants were produced from thin and long cuttings (Table 14).

1.6 Effect of treatments on the mean number of Primary roots produced

The effect of treatments on the number of primary roots produced was significant (Appendix - VI).

Maximum number of primary roots were observed in thick root cuttings of length 15 cm treated with NAA 300 ppm. This was followed by medium thick roots of length 20 cm treated with NAA 300 ppm. Untreated cuttings of medium thickness and 15 cm length recorded the minimum number of primary roots. Statistically this was on par with the following treatment combinations.

Thickness: 3 to 4 cm, Length: 20 cm, Growth regulators: IBA 100 ppm

Thickness: 3 to 4 cm, Length: 20 cm, and no growth regulator treatment (Table 15)

Medium thick roots in general produced greater number of roots than thin and thick cuttings. Increasing the length of root cuttings resulted in the production of higher number of primary roots. Growth regulators recorded an overall increase in the root number when compared with the control. Among the different growth regulators, NAA 300 ppm was superior to others with regard to the production of primary roots (Table 16).

Significant interaction effects were also observed among the different combination of factors. Growth regulators increased the primary root number in medium thick roots than the thin and thick roots. But in untreated cuttings, thin roots were superior. Thick roots treated with NAA 300 ppm recorded the maximum number of primary roots followed by medium thick roots treated with NAA 300 ppm, the difference between the two treatments was not however statistically significant. Increasing the root cutting length had a beneficial effect in primary root number when treated with growth regulators except in NAA 300 ppm treatment. The difference between the two lengths in NAA 300 ppm treatment was not significant. Treatment with NAA 300 ppm recorded higher primary root number in cuttings of both lengths than the remaining treatments. Medium thick and long cuttings was superior in the number of roots produced then remaining combinations of thickness and length.

1.7 Effect of treatments on the number of secondary roots produced

Treatments were found to differ significantly with regard to the production of secondary roots (Appendix - VI).

It was found that significantly higher number of secondary roots were produced in untreated thin cuttings of length 15 cm than others (Table 15).

The overall effect of thickness showed an increased root number with thin roots followed by thick roots, the difference between these two were however not statistically significant. Shorter root cuttings produced comparitively more number of secondary roots than long root cuttings. Increasing the concentration of growth regulators increased the secondary root number. The number of roots recorded was

Table 15. Effect of treatment combinations on the number of roots produced

Thickness (cm)	Length (cm)	IBA 100 Primary roots	IBA 100 Secondary roots	IBA 300 Primary roots	IBA 300 Secondary roots	NAA 100 Primary roots	NAA 100 Secondary roots	NAA 300 Primary roots	NAA 300 Secondary roots	Control Primary roots	Control Secondary roots
		Growth regulators (ppm)									
1 to 1.9	15	6.1	2.4	5.3	3.0	6.4	6.7	6.8	8.3	4.6	14.1
	20	7.8	4.8	5.6	5.0	6.2	4.7	6.6	2.9	5.6	7.9
2 to 2.9	15	7.4	3.4	6.9	3.5	5.1	5.6	7.7	9.5	2.8	4.8
	20	6.9	6.4	6.5	4.6	9.6	6.7	10.8	4.6	4.4	3.6
3 to 4	15	4	5.2	5.0	5.7	4.3	6.2	11.9	7.2	4.5	3.5
	20	3.7	3.5	5.5	4.6	5.1	7.2	7.4	9.3	3.4	6.5

Primary roots

$S.E._m$ ± 0.34

C.D. (0.05) ± 0.97

Secondary roots

$S.E._m$ ± 0.39

C.D. (0.05) ± 1.11

Table 16. Main effects and interaction effects on the number of roots produced

Thickness (cm)	IBA 100 Primary roots	IBA 100 Secondary roots	IBA 300 Primary roots	IBA 300 Secondary roots	NAA 100 Primary roots	NAA 100 Secondary roots	NAA 300 Primary roots	NAA 300 Secondary roots	Control Primary roots	Control Secondary roots	Mean (thickness) Primary roots	Mean (thickness) Secondary roots
1 to 1.9	6.9	3.6	5.4	4.0	6.3	5.7	6.7	5.6	5.1	11.0	6.1	6.0
2 to 2.9	7.1	4.9	6.7	4.0	7.3	6.1	9.2	7.0	3.6	4.2	6.8	5.2
3 to 4	3.8	4.3	5.2	5.1	4.7	6.7	9.6	8.3	3.9	5.0	5.5	5.9
Length (cm)											**Mean (Length)**	
15	5.8	3.6	5.7	4.0	5.3	6.2	8.8	8.3	3.9	7.4	5.9	5.9
20	6.1	4.9	5.8	4.7	6.9	6.2	8.3	5.6	4.4	6.0	6.3	5.5
Mean (Growth regulators)	6.0	4.2	5.8	4.4	6.1	6.2	8.5	6.9	4.2	6.7		

Length (cm)	Thickness (cm) 1 to 1.9 Primary roots	1 to 1.9 Secondary roots	2 to 2.9 Primary roots	2 to 2.9 Secondary roots	3 to 4 Primary roots	3 to 4 Secondary roots
15	5.8	6.9	6.0	5.3	5.9	5.8
20	6.3	5.0	7.6	5.1	5.0	6.2

C.D.(0.05) (Primary roots)

Thickness : 0.31, Length: 0.25
Growth regulator: 0.4
Thickness x Growth regulators: 0.68
Length x Growth regulators: 0.56
Thickness x Length : 0.43

C.D. (0.05) (Secondary roots)

Thickness : 0.35, Length: 0.29
Growth regulator: 0.45
Thickness x Growth regulators: 0.79
Length x Growth regulators: 0.64
Thickness x Length : 0.50

maximum from NAA 300 ppm treatments and control, the difference between these two treatments being not significant (Table 16).

Increasing the root thickness had a beneficial effect on the secondary root development when treated with growth regulators. In untreated cuttings thin roots were superior to medium thick and thick roots. The secondary root number was maximum from water treated thin root cuttings.

Longer roots were better when treated with IBA at both concentrations and NAA at 100 ppm. Treatment with water as control and NAA at 300 ppm produced more number of secondary roots from short root cuttings. Shorter cuttings treated with NAA at 300 ppm recorded the maximum number of secondary roots. The length of cuttings had a significant positive effect with thick cuttings. However, thin and short root cuttings recorded the maximum number of secondary roots (Table 16).

1.8 Effect of treatments on the mean length of primary roots

The mean length of primary roots under different treatments are presented in tables 17 and 18. The effect of treatments on the primary root length was significant. The recorded root length was observed to be the maximum from thin roots of length 15 cm treated with NAA 100 ppm. This was on par with medium thick root cuttings of length 20 cm treated with NAA 300 ppm.

Untreated thick roots of length 15 cm recorded the minimum root length. This treatment was statistically on par with the following treatment combinations.

Thickness: 1 to 1.9 cm, Length: 20 cm, Growth regulator: IBA 300 ppm

Thickness: 2 to 2.9 cm, Length: 20 cm and no growth regulator treatments

Thickness: 2 to 2.9 cm, Length: 15 cm and no growth regulator treatments

There was no significant difference in primary root length between thin and medium thick roots. However they recorded significantly higher length of roots than thick root cuttings. Shorter root cuttings produced longer primary roots. Growth regulators had a beneficial effect on root length when compared to control. NAA at 100 ppm recorded the maximum value, which was followed by NAA 300 ppm. The difference between these two treatments were not statistically significant (Table 18).

The response for the growth regulators was not the same with the different levels of thickness of cuttings. Thin roots treated with NAA at a concentration of 100 ppm recorded the maximum root length which was followed by medium thick roots treated with NAA at 200 ppm. A significant reduction in root length was noticed in all the three different types of cuttings when they were used without any growth regulator treatment. Shorter root cuttings were more effective with growth regulator treatment in increasing the length of primary roots. In untreated cuttings, longer cuttings were better than short root cuttings. Short and long root cuttings, both treated with NAA at 100 and 300 ppm were found to be better than the remaining treatments (Table 18).

The interaction between the effect of thickness and length was not significant (Appendix - VII).

1.9 Effect of treatments on the mean length of secondary roots.

Significant difference was noticed between the effect of treatments on the length of secondary roots that were produced from the cuttings (Appendix - VII). Medium thick roots of length 15 cm treated with NAA 300 ppm recorded the maximum root length. Untreated thick roots of length 15 cm recorded the minimum secondary root length (Table 17).

In general medium thick cuttings were found to be superior to thin and thick cuttings, which were on par. Shorter root cuttings performed better than longer cuttings in the observed character. The application of growth regulators had a beneficial effect on root length when compared to control. Treatment with NAA 300 ppm recorded the maximum value (Table 18).

Significant interaction effects were also observed among the different combination of factors. The effect of growth regulators was different with different levels of thickness. The maximum length of secondary roots was noticed from medium thick roots treated with NAA at 300 ppm. Cuttings of both lengths responded better when treated with NAA at 100 and 300 ppm than when treated with IBA and also when planted without treatment with growth regulators. Shorter cuttings treated with NAA 300 ppm was found to be better than other combination of length of cuttings and growth regulators. The interaction between effect of thickness and length was found significant. Medium thick and short root cuttings were found to be superior to other treatments.

Table 17. Effect of treatments combinations on the length of roots (cm)

Thickness (cm)	Length (cm)	Growth regulators (ppm)									
		IBA 100		IBA 300		NAA 100		NAA 300		Control	
		Primary roots	Secondary roots	Primary roots	Secondary roots	Primary roots	Secondary roots	Primary roots	Secondary roots	Primary roots	Secondary roots
1 to 1.9	15	9.1	3.0	7.4	2.0	12.8	4.3	6.4	3.4	4.7	1.5
	20	6.9	3.3	3.3	1.3	11.4	2.4	10.7	2.6	5.3	2.4
2 to 2.9	15	9.3	2.0	9.6	3.4	8.4	2.4	10.2	6.6	3.7	4.5
	20	6.0	2.3	5.1	1.4	10.5	3.4	11.8	4.1	4.0	1.5
3 to 4	15	4.5	1.4	5.3	2.2	7.8	1.8	10.8	4.1	3.0	1.2
	20	5.7	3.4	6.5	3.6	6.2	3.0	5.8	2.8	6.0	3.4

<u>Primary roots</u>

$S.E._m$: 0.35

C.D. (0.05) : 1.0

<u>Secondary roots</u>

$S.E._m$: 0.23

C.D. (0.05) : 0.67

Table 18. Main effects and interaction effects on the length of roots (cm)

Thickness (cms)	IBA 100 Primary roots	IBA 100 Secondary roots	IBA 200 Primary roots	IBA 200 Secondary roots	NAA 100 Primary roots	NAA 100 Secondary roots	NAA 200 Primary roots	NAA 200 Secondary roots	Control Primary roots	Control Secondary roots	Mean (Thickness) Primary roots	Mean (Thickness) Secondary roots
1 to 1.9	8.0	3.1	9.4	1.6	12.1	3.4	8.5	3.0	5.0	1.9	7.8	2.6
2 to 2.9	7.6	2.2	7.3	2.4	9.4	2.9	11.0	5.4	3.8	3.0	7.0	3.2
3 to 4	5.1	2.4	5.9	2.9	7.0	2.4	8.3	3.4	4.5	2.3	6.1	2.7
Length (cm)											**Mean (Length)**	
15	7.6	2.1	7.4	2.5	9.6	2.8	9.1	4.7	3.8	2.4	7.9	2.9
20	6.2	3.0	5.0	2.1	9.3	2.9	9.4	3.2	5.1	2.4	7.0	2.7
Mean (Growth regulators)	6.8	2.5	6.2	2.3	9.5	2.9	9.2	3.9	4.4	2.4		

Growth regulators (ppm)

Length (cm)	Thickness (cm) 1 to 1.9 Primary roots	1 to 1.9 Secondary roots	2. to 2.9 Primary roots	2. to 2.9 Secondary roots	3 to 4 Primary roots	3 to 4 Secondary roots
15	8.1	2.8	8.2	3.8	6.2	2.1
20	7.5	2.4	7.5	2.5	6.0	2.2

C.D. (0.05) (Primary roots)

Thickness: 0.32, Length: 0.26
Growth regulators: 0.41
Thickness x Growth regulators: 0.71
Length x Growth regulator : 0.58

C.D. (0.05) (Secondary roots)

Thickness: 0.21, Length: 0.17
Growth regulators: 0.27
Thickness x Growth regulators: 0.5
Length x Growth regulators: 0.4
Thickness x Length : 0.30

FIG. 1 EFFECT OF THICKNESS AND GROWTH REGULATORS ON DAYS FOR SPROUTING OF ROOT CUTTINGS

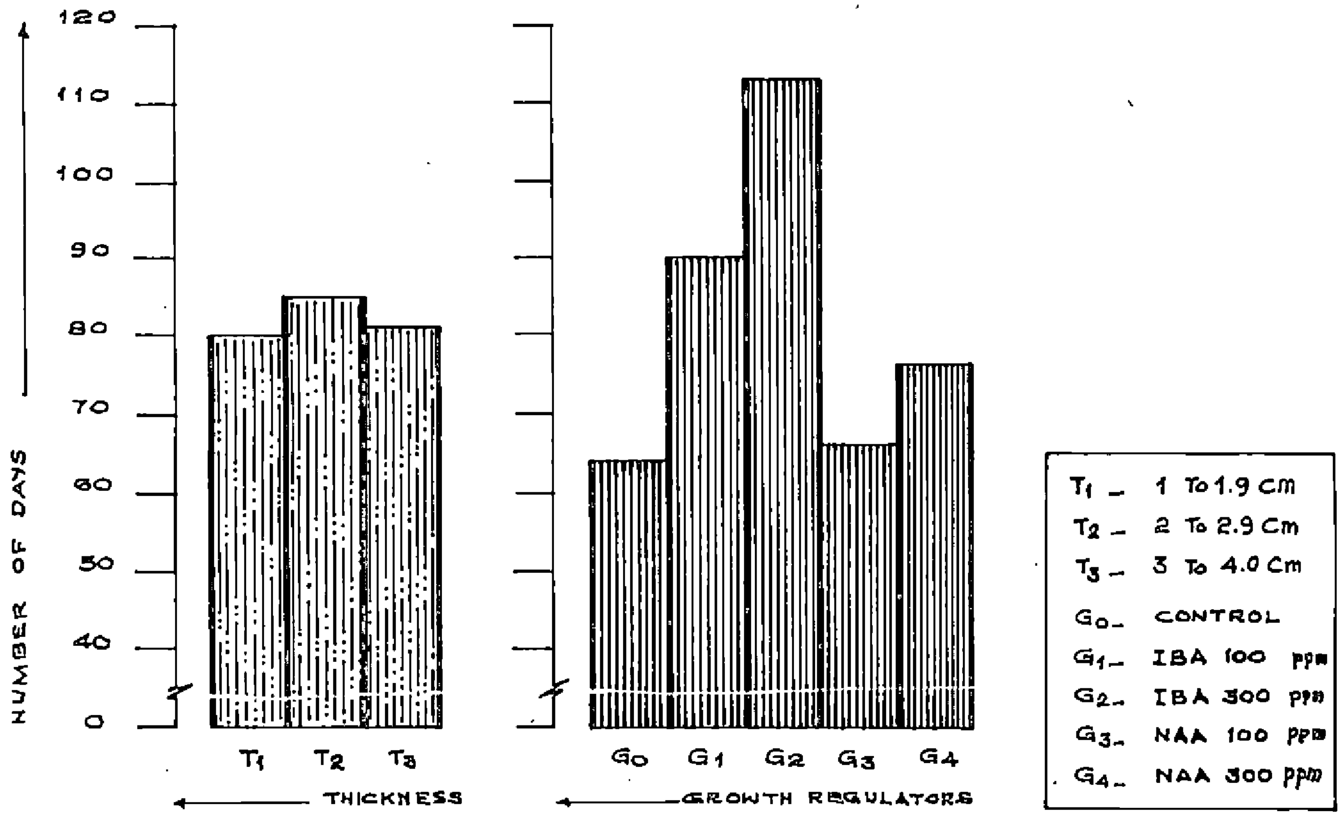


FIG. 2 EFFECT OF THICKNESS AND GROWTH REGULATORS ON HEIGHT OF PLANTS

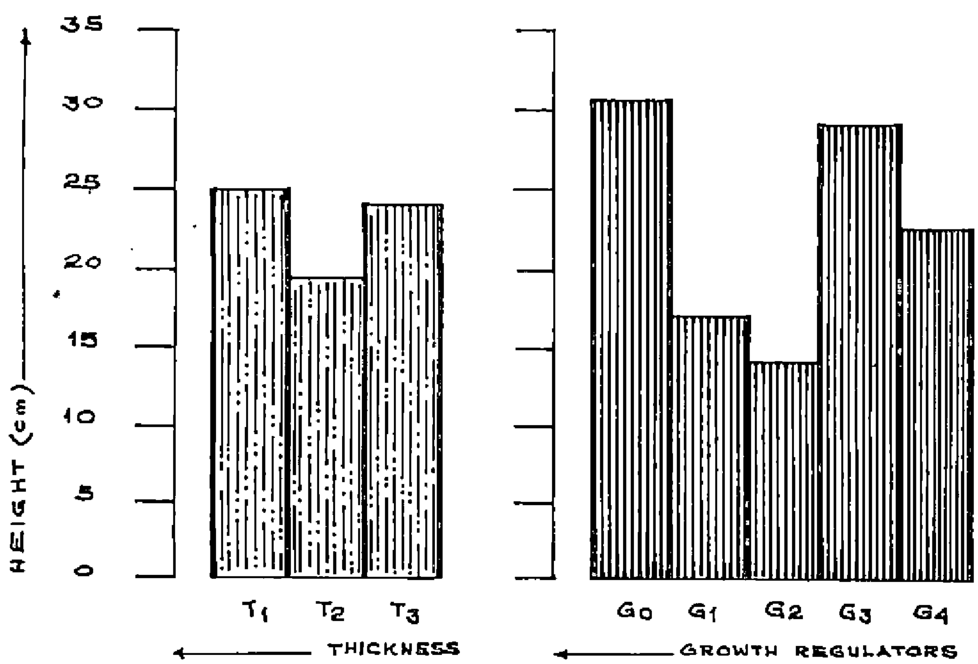
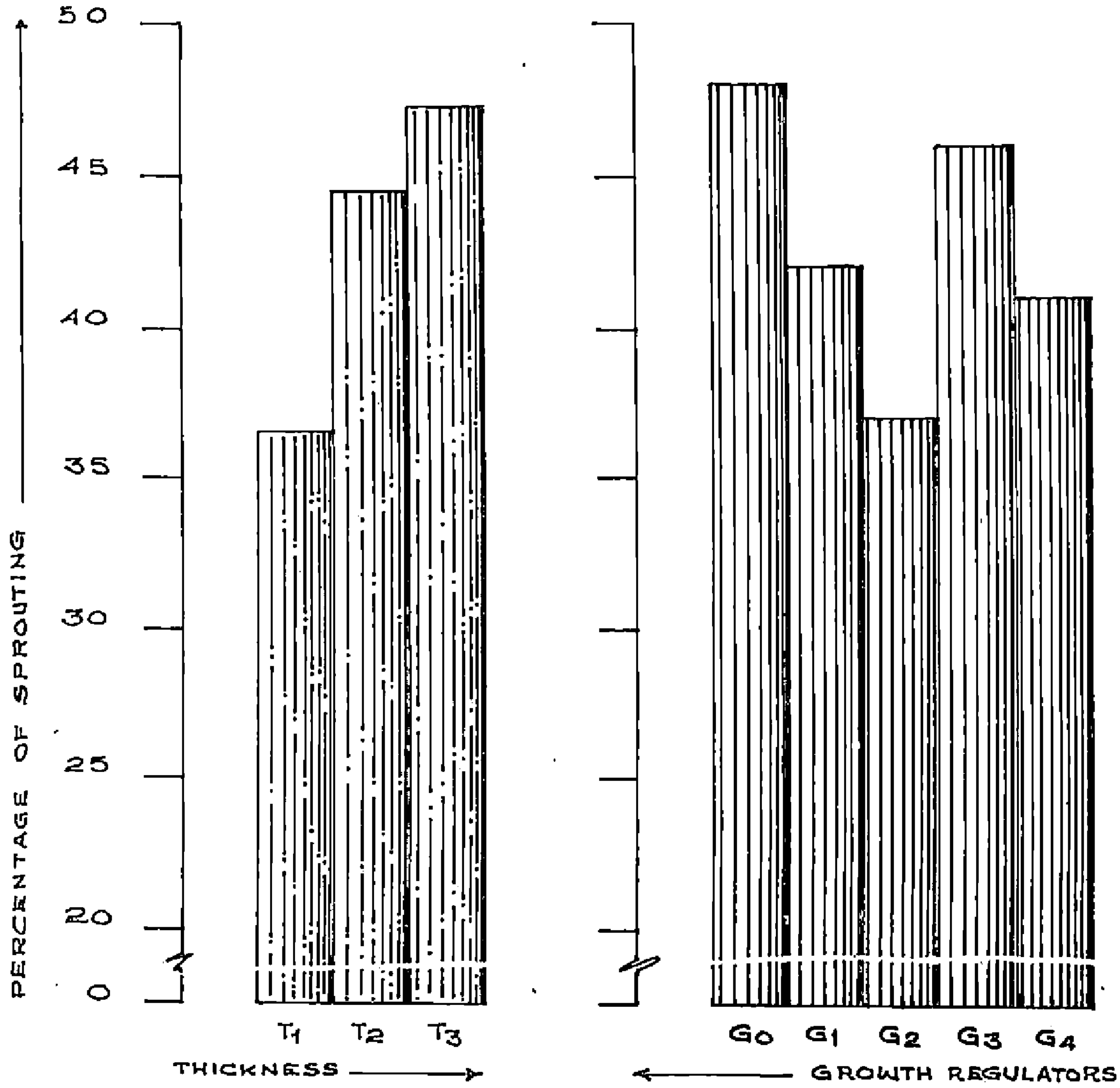


FIG. 3 EFFECT OF THICKNESS AND GROWTH REGULATORS ON PERCENTAGE OF SPROUTING



T_1 - 1 To 1.9 cm	G_0 - CONTROL	G_3 - NAA 100 ppm
T_2 - 2 To 2.9 cm	G_1 - IBA 100 ppm	G_4 - NAA 300 ppm
T_3 - 3 To 4.0 cm	G_2 - IBA 300 ppm	

1.10 Carbohydrate content in roots

Thick root cuttings recorded the maximum carbohydrate content of 9.9 per cent followed by medium thick roots with 7.2 per cent and thin roots with 5.8 per cent.

2. Propagation with stem cutting

Observations recorded 10 days after planting showed that irrespective of the treatments, the cuttings started wilting and after 20 days of planting all the cuttings dried. Hence the study could not proceed further.

3. Propagation through layering

3.1 Layering in mature plants

Four months after layering, the number of layers that rooted was observed. There were no signs of rooting in all the treatment. At random there was callus formations in some layers. Since this did not conform to the statistical design, no analysis could be made. The percentage of rooting was very few in both the seasons.

3.2 Layering in young juvenile plants

Among the 20 plants layered 18 layers rooted. The average number of days taken for rooting was 32. The rooted layers were planted in the nursery of which 14 survived.

3.3 Propagation through stool layering

From the 15 shoots layered, 12 rooted satisfactorily. The success in rooting was observed to be 80 per cent. The layers have been seperated and planted in pots. The growth of plants were satisfactory (Plate 3 and 4).

Plate 3. Rooted stool layers of bread fruit.

Plate 4. A seperated layer showing roots

Plate-3 (x 0.1)

Plate-4 (x 0.12)

DISCUSSION

DISCUSSION

The present investigation was carried out as an attempt to standardise a suitable method of propagation of bread fruit through vegetative means. The results obtained in the present investigation are discussed in this chapter.

Propagation with root cuttings

The root cuttings taken for the experiment were grouped based on the thickness and length. They were treated with growth regulators at different concentrations.

Irrespective of the thickness and growth regulator treatment, cuttings of 5 cm and 10 cm long failed to sprout. Between 15 cm and 20 cm long cuttings, the cuttings of 20 cm length gave higher percentage of sprouting. Increase in the length of cutting enhanced the sprouting percentage. Similar results are reported by Bolt (1982) in pecan root cuttings, where a success of 60, 80 and 100 per cent were obtained from 10 cm, 15 cm and 20 cm long cuttings, respectively. Randhawa and Kishore (1983) got higher success with longer root cutting in 'Kainth' variety of Pyrus pashia. In apple, Robinson and Shwabe (1977) showed that longer root pieces were productive than several shorter roots. Similar studies by Way *et al.* (1955) in apple showed that establishment of independent plants dropped from 90 per cent with roots 18 cm long to 32 per cent with roots 5 cm long.

The subsequent growth of sprouts as observed by the time taken for leaf emergence was faster in 20 cm long cuttings. The number of sprouts produced per cutting was more from 20 cm long cuttings. The plants produced from 20 cm long root cuttings attained more height than 15 cm long cuttings. This again is in agreement with the findings of Bolt (1982) in pecan root cuttings, where he obtained increased shoot length with increase in length of root cutting. Similar results are reported in coffee by Msumbu *et al.* (1982). The increased vigour exhibited by the longer cuttings can be attributed to the higher total carbohydrate reserves. Turovskaya (1969) found that secondary shoots produced from short roots were weak, thin with small leaves. She reasoned it out that in short roots total reserves must have been lower.

From the present investigation it was found that thickness had a significant influence on the sprouting and subsequent growth of sprouts. Percentage of sprouting showed an increasing trend with increasing thickness. Similar results were obtained in bread fruit by Otanes and Ruiz (1956). The number of sprouts produced per cutting were found more in thick roots. The carbohydrate reserves were found more in thick roots. The higher sprouting percentage obtained may be attributed to the increased carbohydrate reserves in thicker roots.

The thin roots were found to sprout on earlier than others. The time taken for leaf production and height attained by the plants also followed a similar trend. The earliness in sprouting in thin cutting may possibly be due to the age of the root cuttings and juvenility may probably play a great role in induction of earliness in such cuttings. The role of juvenility in the sprouting of root cuttings is reported by Garner and Hatcher (1958) in cherry plum and Turovskaya (1973) in apple.

The interaction between length and thickness was significant. In general for sprouting and subsequent growth a combination of higher levels of thickness and length were found superior.

The effect of growth regulators on induction of sprouting from root cuttings was found to be negative.

when the chemicals were used at different concentrations. Indole 3 butyric acid and naphthalene acetic acid at a concentration of 500 ppm inhibited sprouting in the treated cuttings. The lower concentrations of these chemicals produced sprouting but the maximum sprouting was obtained when there was no growth regulator treatment. The leaf emergence was found to be earlier in the absence of any growth regulator treatment. Consequently the height attained by the plants 6 months after planting also showed the similar trend. IBA at 300 ppm produced the minimum sprouting and the most delayed leaf emergence. These findings are in full agreement with the results obtained by Turowskaya in 1977. No response was obtained in apple root cuttings to any growth regulators. Similarly in Coffee Nsumbu et al. (1982) reported that mortality was more in growth regulator treated root cuttings compared to untreated root cuttings. The percentage of cuttings producing leafy shoots were also less in treated cuttings compared to water-treated control.

Auxin suppress root sucker formation. This is reported by Eliasson (1971) for roots of herbaceous species was well as in callus cultures. [1]Robinson and Schwabe in 1977 found that in apple root cuttings application of IBA at 150 mg/l completely inhibited the bud initiation. Hartman and

Kester (1978) has explained that application of rooting substances to root cuttings may inhibit the development of shoots from such root pieces. The situation is explained in shoot cuttings also where auxin application at higher concentration can inhibit bud development, even though root formation is adequate. In the present investigation auxin at higher concentration has suppressed shoot growth but produced better root development.

Auxin produced in shoots is translocated into the roots where it prevents sucker formation. When aerial parts of the plant are removed or injured, root sucker is released as a response to lowered auxin concentration. Eliasson (1971) from his work on Pohlia tremula concluded that lowering of auxin content is the decisive factor in the release of sucker from the roots. Hormonal regulations of bud initiation in roots was suggested by the absence of buds on attached roots but a rapid formation after detachment. In the attached roots auxin from the aerial part of the tree would normally prevent bud initiation. The same effect is seen in the present investigation with the external application of auxin which suppressed bud initiation at higher concentration and maximum sprouting being obtained in water treated controls.

Growth regulators had a significant interaction with thickness and length. Higher levels of thickness and length with no growth regulator treatment showed the maximum success. This may be due to a combination of higher carbohydrate reserves obtained and lower auxin content that aided in better sprouting. [2]Robinson and Schwabe (1977) suggested that accumulation of carbohydrates and depletion of IBA is suitable for rapid and long term regeneration from root cuttings in apple.

The rooting of cutting was influenced by the treatments. The number and length of primary roots produced were more from medium thick and thin roots. The root production was also more from 15 cm long cuttings compared to 20 cm long cuttings. The increased rooting obtained from medium thick and thin cuttings may be due to the younger age of these cuttings.

The influence of growth regulator in rooting was found to be significant. NAA 200 ppm recorded the maximum value for root number and root length (Plate 5). Absence of any growth regulator treatment resulted in poor root development. Turovskaya (1977) reported similar results in apple root cuttings, where application of growth regulators like auxin, had a beneficial effect on root development although it

Plate 5. Effect of NAA 300 ppm on number and length of newly formed roots.

Plate-5 (x0.36)

suppressed shoot development. Plant (1940) also reported good root development from root cuttings of seakale treated with 0.02 per cent NAA. The results are in agreement with the explanation put forth by Hartman and Kester (1978).

IBA though considered as a rooting hormone did not show any beneficial effect on the root cuttings. NAA which is effective in both shoots and roots produced more root initials than IBA in the present study.

Propagation with Stem cuttings

Propagation with stem cuttings is generally attempted in fruit, crops as this method is inexpensive and easy. The use of growth regulator is also now in practice for enhancing the rooting capacity. In the present investigation attempts to propagate bread fruit plants with stem cuttings failed even though the cuttings were treated with growth regulators at different concentrations. Muzik (1948) and Hamilton et al. (1983) has reported success with stem cuttings in bread fruit. However such a result could not be reproduced in the present study.

The age of the tree from which cuttings were taken would have greatly influenced the extent of rooting and the failure may be probably due to the old age of the mother trees. Cuttings for the present study were taken from trees over 20 years old. Reports of rooting of difficult to root species are there from juvenile cuttings. Rajan and Ram (1983) reported that in mango, juvenile cuttings rooted well where as non juvenile ones (from 30 year old trees) did not. The reciprocal effect of age on rooting is reported by Wally *et al.* (1981) in guava, Vasquez and Gesto (1982) in *Castanea sativa* and Davies (1984) in *Ficus pumila*. In jack, Chatterjee and Mukherjee in 1980 reported that non leafy cuttings failed to root even with growth regulator treatments. Garner (1929) generalised from his study with different species that higher and earlier rooting is obtained in cutting from one year old seedling than from older trees. Bonner and Galston (1952) reported that although many difficult to root species respond well to externally applied auxin, still other species do not respond at all. In these latter plants, some factor other than auxins must have limited root initiation.

Propagation through layering

In the present investigation layering done in mature plant failed to produce any rooting in both May-June and September - October. The symptoms of callus formation was also very little. The application of growth regulators had no influence on rooting of layers.

High success in rooting was obtained through layering of one year old plants even without the application of growth regulators. Similar results are reported in several difficult to root plants. Srinivasan (1961) got 100 per cent success with layering in 2 years old jack tree seedlings. He reported that young jack fruit plants which are still in juvenile stage gave better rooting response compared to grown up plants. Lingarajappa (1982) found that in jack layers, juvenile shoots formed roots 30 days earlier than mature shoots. Absence of juvenility may be the possible reason for the failure of rooting in air layers of mature plants. The regeneration capacity is less in old plants than in young plants.

From the present investigation, stool layering is found highly successful with young plants of bread fruit. Investigation on stooling in one year old jack fruit plants has been successful as reported by Chatterjee and Mukherjee (1980). Success with stool layering in mango is also reported. (Singh and Srivastava, 1982).

SUMMARY

SUMMARY

The investigation was carried out at the Department of Horticulture, College of Agriculture, Vellayani during 1984-85 to standardise the most suitable method of vegetative propagation of bread fruit. Trials were conducted on propagation with different vegetative parts. The effect of growth regulators on the success of different methods were also studied. The salient findings of the investigation are summarised below.

1. Root cuttings with a length of 5 cm and 10 cm and those treated with IBA 500 ppm and NAA 500 ppm did not give any satisfactory results.

2. The thickness of roots, length of cuttings and growth regulators had a significant influence on the time taken for sprouting. Thin roots and longer cuttings were found earlier in sprouting. Growth regulators at higher concentrations delayed sprouting and earlier sprouting was recorded from water treated control and treatment with NAA 100 ppm. The earliest sprouting was obtained from untreated thin cuttings of length 15 cm.

3. The percentage of sprouting increased with increasing root thickness and cutting length. Growth regulators

had a negative effect on sprouting. Water treated controls and treatment with NAA 100 ppm gave comparitively higher percentage of sprouting.

4. The number of sprouts produced per cutting was more in thick roots (3 to 4 cm thickness) and long cuttings (20 cm length). Growth regulators did not have any effect on the number of sprouts produced.

5. In general root cuttings of 1 to 1.9 cm thickness gave earlier leaf emergence. Similarly 20 cm long cutting gave earlier emergence of leaves than 15 cm long cuttings. Among the growth regulators tried, water treated control and NAA 100 ppm gave earlier leaf emergence. Among the different treatment combinations tried, thin roots of 20 cm length treated with NAA 100 ppm gave the earliest leaf emergence.

6. The height of plants attained after six months was more from thin root cuttings and cuttings of 20 cm length. Growth regulators had a negative influence on the height of the plants and height attained was more when there was no growth regulator treatment. The maximum height of 42.5 cm was given by a treatment combination of 1 to 1.9 cm thickness, 20 cm length and growth regulator NAA 100 ppm.

7. Among the treatments compared the primary roots produced from sprouted root cuttings were more from medium thick and thin roots, 20 cm long cutting and from cuttings treated with NAA 300 ppm. A treatment combination of 3 to 4 cm thickness, 15 cm length and NAA 300 ppm recorded the maximum number of primary roots.

8. The secondary root number was more from 1 to 1.9 cm thick roots, 15 cm long cuttings and from those treated with NAA 300 ppm.

9. The primary root length was more from medium thick and thin roots. The secondary root length recorded was more from medium thick roots. 15 cm long roots recorded the maximum length of both primary and secondary roots. Among the growth regulators tried, NAA 100 and 300 ppm produced increased primary root length over the remaining treatments. The secondary root length was more from a treatment with NAA 300 ppm.

10. The carbohydrate content was found to increase with increase in the root thickness.

11. Layering done in mature plants was not successful in both the seasons.

12. Layering done in young juvenile plants was found to be highly successful as 18 layers rooted out of the 20 shoots layered.

13. Stool layering of young plants gave 80 percent success in rooting.

14. Propagation with stem cuttings was not found successful.

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* - Originals not seen

APPENDICES

APPENDIX - I

Analysis of variance table for days for sprouting

Source	df	Mean square	F ratio
Treatments	29	1259.45	239.89**
Thickness	2	120.05	22.87**
Length	1	608.03	115.82**
Growth regulators	4	4903.77	934.05**
Thickness x Growth regulators	8	1668.03	317.72**
Length x Growth regulators	4	191.93	36.56**
Thickness x Length	2	624.02	118.86**
Thickness x Length x Growth regulators	8	87.62	16.69**
Error	30	5.25	
Total	59		

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX - II

Analysis of variance table for percentage of sprouting[@]

Source	df	Mean squares	F ratio
Treatment	29	1.16	6.3**
Thickness	2	4.31	23.55**
Length	1	2.02	10.99**
Growth regulators	4	1.56	8.5**
Thickness x Growth regulators	8	216.12	7.81**
Length x Growth regulators	4	79.85	2.9*
Thickness x Length	2	86.45	3.14
Thickness x Length x Growth regulators	8	24.23	0.88
Error	30	27.57	
Total	59		

@ Arcsin transformation was used for data transformation

* Significant at 5 percent level

** Significant at 1 percent level

APPENDIX - III

Analysis of variance table for number of sprouts per cutting[O]

Source	df	Mean square	F ratio
Treatments	29	0.039	4.07**
Thickness	2	0.132	13.69**
Length	1	0.058	5.98**
Growth regulators	4	0.023	2.36
Thickness x Growth regulators	8	0.036	3.73**
Length x Growth regulators	4	0.009	0.93
Thickness x Length	2	0.063	6.5**
Thickness x Length x Growth regulators	8	0.034	3.53**
Error	30	0.0096	
Total	59		

O Square root transformation was used for data transformation

* Significant at 5 percent level

** Significant at 1 percent level

APPENDIX IV

Analysis of variance table for the days for leaf emergence

Source	df	Mean Square					
		1st	2nd	3rd	4th	5th	6th
Treatments	29	1280.30	1298.38	1240.47	1235.77	1291.72	1284.04
Thickness	2	98.47	115.28	173.88	291.66	345.75	262.94
Length	1	608.03	589.06	836.31	1083.75	1696.00	1450.38
Growth regulators	4	5207.02	5512.91	5610.36	5554.99	5458.38	5570.56
Thickness x Growth regulators	8	1593.93	1543.97	1356.49	1349.65	1484.94	1460.16
Length x Growth regulators	4	134.48	101.06	58.89	55.3	95.91	79.13
Thickness x Length	2	741.06	466.47	233.19	133.38	264.00	255.25
Thickness x Length x Growth regulators	8	90.52	136.59	95.23	83.13	55.95	58.80
Error	30	4.31	5.13	6.07	5.35	5.48	7.52
Total	59						

F - ratio					
1st	2nd	3rd	4th	5th	6th
296.60**	252.93**	204.47**	230.98**	235.57**	170.83**
22.81**	22.46**	28.66**	54.52**	63.06**	34.90**
140.86**	114.75**	137.85**	202.57**	309.3**	192.95**
1206.26**	1073.95**	920.1**	1038.32**	995.45**	741.1**
369.25**	300.77**	223.6**	252.27**	270.81**	194.26**
31.25**	19.69**	9.71**	10.34**	17.49**	10.53**
171.68**	90.87**	38.44**	24.93**	48.15**	33.90**
20.97**	26.61**	15.71**	15.54**	10.20**	7.02**

**Significant at 1% level.

APPENDIX - V

Analysis of variance table for the height of plants

Source	df	Mean square	F ratio
Treatments	29	157.47	224.58**
Thickness	2	202.82	289.26**
Length	1	58.02	82.74**
Growth regulators	4	633.2	903.06**
Thickness x Growth regulators	8	139.4	198.81**
Length x Growth regulators	4	16.51	23.53**
Thickness x Length	2	58.70	83.72**
Thickness x Length x Growth regulators	8	33.94	48.4 **
Error	30	0.7	
Total	59		

** Significant at 1 percent level

APPENDIX - VI

Analysis of variance table for number of roots produced

Source	df	Mean square		F ratio	
		Primary roots	Secondary roots	Primary roots	Secondary roots
Treatments	29	8.5	12.04	37.87**	40.72**
Thickness	2	8.8	3.06	39.21**	10.35**
Length	1	2.56	3.08	11.42**	10.43**
Growth regulators	4	29.0	20.02	129.26**	67.7 **
Thickness x Growth regulators	8	6.74	15.94	30.05**	53.91**
Length x Growth regulators	4	1.91	7.79	8.51**	26.33**
Thickness x Length	2	8.28	8.01	36.9 **	27.09**
Thickness x Length x Growth regulators	8	4.01	10.65	17.88**	36.01**
Error	30	0.22	0.3		
Total	59				

** Significant at 1 percent level

APPENDIX - VII

Analysis of variance table for mean length of roots

Source	df	Mean square		F ratio	
		Primary roots	Secondary roots	Primary roots	Secondary roots
Treatments	29	15.16	2.86	63.63**	26.68**
Thickness	2	18.94	1.83	79.48**	17.05**
Length	1	3.85	0.54	16.16**	5.05*
Growth regulators	4	54.36	5.24	228.14**	48.86**
Thickness x Growth regulators	8	7.99	2.32	33.54**	21.61**
Length x Growth regulators	4	6.42	2.33	26.95**	21.71**
Thickness x Length	2	0.35	7.02	1.46	65.51**
Thickness x Length x Growth regulators	8	11.27	1.99	47.31**	18.6 **
Error	30	0.24	0.11		
Total	59				

* Significant at 5 percent level
** Significant at 1 percent level

STANDARDISATION OF PROPAGATION TECHNIQUES IN BREAD FRUIT (*Artocarpus altilis* (Park.) Fosberg)

By

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ABSTRACT OF THE THESIS
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MASTER OF SCIENCE IN HORTICULTURE
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1986

A B S T R A C T

Investigations were carried out at the Department of Horticulture, College of Agriculture, Vellayani during 1984-85 to standardise the most suitable method of vegetative propagation of bread fruit. The experiment was conducted in completely randomised design with root and stem cuttings and layering in order to find out the optimum thickness and length of roots and shoots and also the influence of growth regulators in enhancing the success with each of these methods.

From the investigations it was found that root cuttings were the most reliable and successful propagules compared to stem cuttings and layers. Thick roots were found to give comparitively more success in percentage of sprouting and the number of sprouts per cutting. Earlier sprouting and faster growth of the sprouts were recorded from thin roots. The root development from the root cuttings was more from medium thick and thin cuttings. Longer root cuttings were more suited for propagation since they performed better in all characters except in secondary root development. Growth regulators had a negative effect on sprouting of root cuttings. Higher success in sprouting, earlier sprouting and subsequent growth was obtained from untreated cuttings and also from those treated with NAA at lower concentration. However root

development from the cuttings was found to be enhanced by growth regulator treatment compared to control. Among the growth regulators tried, NAA 300 ppm gave better results in the development of both primary and secondary roots.

Propagation with stem cuttings and layering on mature plants was found to be unsuccessful, but layering in young juvenile plants was found highly successful. Stool layering in bread fruit is also found to give higher percentage of success.