PROPAGATIONAL STUDIES ON COCOA

(*Theobroma cacao* L.)

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Propagational studies on cocoa (*Theobroma cacao* L.)" is a bonafide record of research work done by me during the course of research work and 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.

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17th November, 1979.

CERTIFICATE

Certified that this thesis entitled "Propagational studies on cocoa (*Theobroma cacao* L.)" is a record of research work done independently by Shri.Keshavachandran,R. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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C O N T E N T S

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LIST OF TABLES

10a to c. Root growth parameters of cocoa seedlings at various intervals sown in different months. February sowing.

11a to c. Dry weight of cocoa seedlings at various intervals sown in different months. February sowing.

12a to c. Shoot growth parameters of cocoa seedlings at various intervals sown in different months. March sowing.

13 a to c. Root growth parameters of cocoa seedlings at various intervals sown in different months. March sowing.

14a to c. Dry weight of cocoa seedlings at various intervals sown in different months. March sowing.

15a to c. Shoot growth parameters of cocoa seedlings at various intervals sown in different months. April sowing.

16a to c. Root growth parameters of cocoa seedlings at various intervals sown in different months. April sowing.

17a to c. Dry weight of cocoa seedlings at various intervals sown in different months. April sowing.

18a toc. Shoot growth parameters of cocoa seedlings grown in different sizes of bags. December, February and March sowings.

19a to c. Root growth parameters of cocoa seedlings grown in different sizes of bags. December, February and March sowings.

20a to c. Dry weight of cocoa seedlings grown in different sizes of bags. December, February and March sowings.

21a to c. Shoot growth parameters of cocoa seedlings grown in different media. December, February and March sowings.

22a to c. Root growth parameters of cocoa seedlings grown in different media. December, February and March sowings.

23a to c. Dry weight of cocoa seedlings grown in different media. December, February and March sowings.

24. Germination of cocoa seeds under various conditions of storage.

25. Root growth of cocoa seedlings at various intervals.

26a. Rooting data of cocoa semi-hard wood cuttings treated with different plant growth regulators. Mist chamber method.

26b. Rooting data of cocoa semi-hard wood cuttings treated with different plant growth regulators. Polythene sheet method.

27. Budding of cocoa seedlings.

28. Green budding of cocoa seedlings.

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

INTRODUCTION

Cocoa is one of the most important beverage crops of the world after tea and coffee. Though cocoa has been introduced to India about fifty years back, its commercial importance has been felt only during the last few years. The cultivation has been gaining ground during the last six years because of the heavy demand in the world market and the consequent high prices. The world production of cocoa increased from 18,000 tonnes in 1850 to 15,00,000 tonnes in 1975. This quantity is hardly sufficient to meet 50 per cent of the requirements (Nair,1979). The world demand according to the F.A.O. report is increasing at least by 3.9 per cent per annum and the consumption is likely to be increased to 2.4 million tonnes by 1985.

Out of the estimated 7981 hectares under cocoa in India, Kerala contributes around 5548 hectares followed by Karnataka with 2240 hectares and Tamil Nadu with 193 hectares. The estimated production in 1976 is around 400 tonnes while the demand by 1985 will be around 20,000 tonnes even for meeting the internal consumption. Further there are immense possibilities of exporting cocoa beans or cocoa products in view of the shortage in the world market. During 1973-74, India imported cocoa beans and cocoa products to the tune

of 1134.3 tonnes valued at 240.6 lakhs of rupees. Since then, the quantity imported is being reduced mainly because of import restrictions and to a certain extent due to the increase in the internal production. Even during 1973-'74, India exported 1699.0 tonnes of cocoa products valued at 95.5 lakhs of rupees which indicates the immense possibilities for the export of cocoa products (Nair,1979).

In a perennial crop, the selection of planting material is very important to perpetuate high yielding, uniform quality plants. This becomes more important with cocoa which is heterozygous and highly cross pollinated. The seedlings are the main planting material at present and the production of quality seedlings has not received serious attention. Hence, standerdisation of the seedling selection is essential.

Production of true-to-type progeny by resorting to vegetative methods of propagation is another way of obtaining uniform, high yielding plants. Rooting of cuttings and different methods of budding have been tried in other cocoa growing countries of the world with encouraging results. When compared with rooting of cuttings, budding has an additional advantage in that it can also be used for top working the uneconomical, inferior plants. It is therefore necessary that methods of vegetative propagation

suitable under the agro-climatic conditions of Kerala are standardised.

Standardisation of nursery practices, such as the size of pots or polythene bags to be used and formulating suitable potting medium to be used is also important.

Under the above circumstances, a study has been undertaken at the College of Horticulture with the following objectives.

1. To standardise the criteria for selecting the pods, seeds and seedlings.
2. To determine the optimum size of polythene bags and to formulate the suitable potting medium to be used in the nursery.
3. To standardise the methods of vegetative propagation.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Cocoa, though a comparatively new crop of economic importance to India, is one that has been investigated upon rather extensively in other important cocoa growing areas of the world. The present study deals with only the propagation aspects. An attempt has been made to provide a brief review of the literature available on the different aspects on propagation.

1. SEED PROPAGATION

1.1 Size of Polythene Bags

Small differences exist in the various aspects of seed propagation as followed in the cocoa growing countries. Size of polythene bags, thickness and colour of polythene film used constitution of potting media, method of sowing the seed, and germination process are some of the aspects that have received the attention of research workers. The size of polythene bags or pots in relation to the growth of the plant has been studied by several workers. Capriles and Gonzalo (1965) found that the growth of cocoa seedlings in plastic bags of 15 cm diameter holding six kg of potting mixture was slightly better than in smaller bags containing lesser quantities of potting medium. Le Brown *et al.* (1967) recommended

12" x 7" size black polythene bags for raising cocoa seedlings. But according to Leach et al.(1971), in Malaysia, polythene bags of 30 x 20 cm were being used when the period in the nursery was four to five months. They also found polythene bags of 23 x 18 cm or 25 x 18cm size to be quite sufficient, if the period in the nursery was only two to two and a half months.

Shepherd (1976) had given specific recommendation on the length, width, gauge, perforation and colour of polythene bags as well as the quantity of potting mixture that can be filled. He indicated specific types of bags that could be used depending upon the period for which the seedlings were retained in the nursery. Wood(1978) suggested the use of polythene bags of 35 x 10 | 12|cm size for retaining the seedlings in the nursery upto five months. Thus a relationship between the size of polythene bags and the duration of the nursery life of cocoa seedlings has been established.

1.2 Potting Media

As in the case of other crops, attempts to formulate a suitable potting medium for cocoa has been made by several workers. Pyke (1935) obtained the best germinatio with calcareous washed, beach sand. Whitehead (1954) reported that a mixture of seven parts loam, three parts

dried farmyard manure and two parts sand gave fairly uniform growth. According to Wessel (1966) germination was slightly better on heavy soils; but subsequent growth was better on lighter soils. Atanda and Jacob (1970) obtained higher germination percentage in sawdust. However, Shepherd (1976) suggested that bags need be filled with top soil of good stable structure; a sandy-clay loam texture being favourable to the growth of cocoa seedlings. If the soils lack organic matter, he recommended incorporating 20 per cent coarse sand and well rotted farmyard manure. Wood (1978) reported that in West Africa top soil alone was used for filling the bags.

1.3 Sowing

Cocoa seed is epigeal in its growth and the cotyledons are raised above the soil surface by the growth of the root.

It is better to plant the seeds with hilum or scar end downwards to prevent the development of distorted seedlings. The seeds can also be sown on their sides, laying them flat (Urquhart, 1961; Wood,1978). Shepherd (1976) reported that the cocoa seeds should be sown with their ling axis in a horizontal plane or with their hilum pointing downwards. According to him,sowing of seeds with

with the hilum pointing upwards was liable to distort the hypocotyl and the radicle consequent to which the seedling growth would be weak, with low recovery.

The depth of sowing is also important. Seeds should be sown no more than 1 cm below the surface of the potting medium (Shepherd, 1976; Wood, 1978).

1.4 Germination

Obtaining earlier germination, higher percentage of germination and better viability have been the problems which received the attention of investigators. Pyke(1935) obtained earlier germination by soaking the seed in water for an hour at 80°F, 95°F and 104°F, but there was little increase in percentage over unsoaked in the final results.

Escamilla et al. (1948) reported quicker and higher total percentage germination by removing the outer skin. Urquhart (1961) suggested that there was no need to remove the mucilage and that good seed should give not less than 80 per cent germination.

According to Boroughs and Hunter (1961), cocoa seeds lost viability after 16 minutes in water at 52°C while immersion for four minutes at 20°C reduced the viability to six per cent.

Atanda and Jacob (1970) reported that the final percentage germination was negatively correlated with time

for final and 50 per cent germination. They also found that peeled seeds germinated quicker with better percentage of germination.

Shepherd (1976) recommended that seeds which do not germinate within 15 days should be discarded as late germinating seeds are normally less vigorous. Wood(1978) also reported that germination of a batch of seed would be usually complete within two weeks and the rate of germination should be at least 90 per cent.

1.5 Storage

The cocoa seed is non-resting and it is ready for germination when the pod is ripe and normally loses its capacity to germinate after a comparitively short period of storage. The factors involved in deterioration of pods under normal conditions are desiccation, fungal attack and senescence which is generally marked by the germination of the bean in the pod.

In the case of low temperature storage deterioration was caused by chilling (Dyke, 1934); Dyke et al, 1934). Dyke (1935) obtained 95 per cent effective germination after 14 days of storage at an average temperature of 60°F while temperatures of 50°F and 45°F completely destroyed viability even after two days. However, a temperature of 60°F gave beans of normal germination percentage even after twenty days. Sink and Rochelle (1964) reported that beans stored at 50°C failed to germinate even after 15 days while

those stored in ventilated glass containers with 40 per cent relative humidity had a germinating capacity of 72 per cent even after 90 days.

In trials conducted in Nigeria, mucilage free cocoa seed dried at 29°C for 8 hours, treated with Captan at a rate of 1g per 100 seeds and stored in dry charcoal at 21°C showed 35 per cent germination after four weeks storage and 14 per cent after eight weeks storage. Drying at temperature of 23 to 29°C for more than 10 hours resulted in much lower germination percentages. The viability of the seeds was rapidly destroyed by storage in a sawdust-sodium chloride medium after drying, and by storage at temperatures below freezing point either with or without drying (Are, 1964). Woodstock et al. (1967) reported that seeds germinated at 25 to 30°C were killed by chilling for 30 minutes in water at 2 to 4°C.

Aghiru (1970) found that beans partially dried in a stream of carbondioxide or nitrogen and stored at 25 to 28°C remained viable for upto 60 days, while those dried in air lost viability within 45 days. Storage of artificially dried beans in the absence of air reduced their viability. A moisture content of about 50 per cent gave high percentage of germination within 30 days and reduced deterioration.

1.6 Root System

Zevallos (1968) found that during the four month period after germination, the relative lengths of the taproot and of the stem remained the same. After that, the stem grew more rapidly than the tap root.

Dyanat - Nejad (1971) further found that cotyledons and the tap root most markedly influence each other during growth. They also found that the root system is determined within 15 days after germination.

2. VEGETATIVE PROPAGATION

2.1 Rooted Cuttings

Although several methods of vegetative propagation have been tried in cocoa, and rooting of cuttings and budding have given encouraging results, attempts to increase the percentage of rooting, improving the take of buds and obtaining proper plant types, have been made by cocoa research workers.

Pyke (1931) reported that the material for cuttings should be taken soon after the leaves had become mature, the stems being hard but still green. Six inches was suggested as a suitable length for the cutting. Cheesman and Spencer (1936) observed that the shoots of the current flush were suitable for rooting. Semihardwood cuttings were found more suitable than hardwood cuttings(Anon,1951).

Leafless cocoa cuttings do not normally produce roots even under optimum conditions including suitable treatments with root inducing substances. In the case of the few cuttings which produce roots, the roots rot after a short period. However the leaf lamina on a cutting can be reduced by one third or two third without greatly affecting root formation (Evans, 1951).

2.1.1 Plant growth regulators.

Use of growth substances increased rooting of cocoa cuttings from 5 to 30 per cent, the concentrated dip being preferable to a 24 hour dilute dip (Anon 1946).

Richards (1948) reported that concentrated dips for one second using indolyl-butyric acid, potassium indolyl-butyrate and a mixture of indolyl butyric acid, phenyl acetic acid and naphthalene acetic acid gave significant increases in percentage of cuttings rooted and in the mean root length.

Garcia and Naundrof (1950) tried 3-indole butyric acid (IBA), 3-indole acetic acid (IAA), α-naphthylene acetic acid (NAA) and 2,4-dichlorophenoxy acetic acid (2,4-D) for rooting cocoa cuttings. They reported that IBA markedly increased the rate and percentage of rooting as well as the number of roots produced. The dusting method of application was reported to be better than the dip method. However, Evans (1951) found the quick dip

method convenient. The best treatment according to him was a mixture consisting of equal parts of NAA and IBA at a total concentration of 8 to 10 mg per ml of 50 per cent alcohol for stem cuttings and 4 to 5 mg per ml for single node or single leaf cuttings.

Alvim and Duarte (1954) recommended 0.7 or 0.8 per cent IBA in either 60 per cent alcohol or talc as the best growth substance formulation for rooting of cocoa cuttings. The addition of fungicides Phygon XL or SR-406 in powder form to the talc formulation at the rate of 1:3 significantly increased the percentage of rooting.

Garcia Brand (1954) reported that immersion of cuttings in Zineb (Dithane Z-78) solution (32g per 4 gal of water) followed by dipping their bases in IBA (5 mg per ml of 50 per cent alcohol) gave the best results.

Edward (1961) suggested that cocoa cuttings be treated with 8000 ppm IBA for best results while Cubato (1961) recommended NAA at 8000 ppm in powder form. Bouma and Ringeling(1962) obtained 84 per cent rooting by treating with 4000 ppm IBA. But Kailasem et al. (1964) found a mixture of IBA and NAA at 5000 ppm to be the best for rooting.

Bhandary and Shivashankar (1974) obtained 100 per cent rooting of cocoa cuttings under intermittent mist with "Rootone" and 73 per cent with IBA 2500 ppm. They were

of the view that in general the rooting percentage decreased with increase in concentration. However they reported that IBA produced more roots and greater length of roots at higher levels while the roots were shorter, thicker and brittle with NAA.

2.1.2 Media and propagators.

Changing the constitution of media and using propagating units with control devices for various environmental factors are known to influence the percentage of rooting.

Pyke (1931) suggested that the cuttings be inserted in coarse sand in a solar propagator. Transpiration was checked by using cuttings with mature leaves and keeping the air around the cuttings humid by placing porous pots filled with water at one foot intervals among the cuttings. A double layer of cloth was then spread over the top and kept moist, thus enclosing the cuttings in a sort of tent. Pyke (1933) reported that cuttings were rpoted under shade in portable wooden glass lighted frames. He suggested fine white sand or medium calcareous sand, overlying successive strata of fine and coarse sand as the most successful rooting medium.

According to Cheesman and Spencer (1935,1936)cuttings must be set in six inches of calcareous sand overlying one foot of coarse gravel and large stones for obtaining better

rooting. They also pointed out the importance of maintaining a practically saturated atmosphere within the frames while providing the correct amount of light which must not be sufficiently strong to raise the temperature and increase transpiration or weak enough to retard photosynthesis. Escamilla et al.(1948) used soil with a 10 cm capping of organic material as the rooting medium. Palm fibre and sand was reported to be the best rooting.medium under Brazilian conditions (Anon,1951).

Lipp (1953) used polythene for rooting cuttings, storing, stratified seeds and for wrapping balled root systems when transplanting. Floor (1954) wrapped cuttings in polythene for increased rooting and also stored plants in it without water for several weeks. Garcia (1954) obtained 66 per cent rooting with coffee silver skin and 52 per cent with sawdust as the rooting medium.

Archibald (1955) described a method of rooting cocoa cuttings in a bed of soil by covering them with a sheet of polythene. 57 per cent rooting resulted with clone S-36 compared with 75 per cent usually obtained with this clone in concrete bins. The new method had the advantage, however, of being cheap in materials and labour.

The value of polythene in rooting cuttings lies in its ability to conserve moisture while allowing diffusion of gases (McKelvie,1957). Moreover it is tough,chemically

inert and is not attacked by fungi. He also observed that covering the cuttings with polythene sheet was cheaper, simpler and more efficient. The hardness of cuttings rooted under polythene was greater than with any of the alternative means of propagation so that there was no need for close control over the environment. The cuttings under polythene sheet were in nearly perfect condition and could tolerate greater external changes. With polythene sheet frequent attention was not needed to keep the atmosphere saturated.

Alvim (1953) used sawdust as the rooting medium while Harris (1953) suggested sawdust treated with a solution of potassium indole butyrate and potassium naphthalene acetate which gave 75 to 100 per cent strike and the roots were in clusters of 6 to 11, and 3.5 to 4.0 inches long after four weeks.

Malins-Smith (1954) described a pit 3' x 5' x 20" as a propagating unit. A jute cover was used and sawdust was the rooting medium. The cover was kept constantly wet. The rooting was reported to be better than in conventional propagators.

Murray (1954) described producing rooted cuttings in baskets in one operation at a substantial saving in cost. The cuttings were inserted in baskets with a central core of

rooting medium surrounded by potting soil. The baskets were kept in a glasshouse with a cetrifugal humidifier maintaining 100 per cent humidity.

Pirez (1954) comparing seven media for rooting cocoa cuttings suggested that fresh and decomposed rice husks and sand gave the highest strikes of 84.5, 86.5 and 63.5 per cent followed by fresh sawdust, vegetable charcoal, decomposed wood and decomposed sawdust.

Edward (1961) reported that cuttings rooted in leached sawdust in 28 days and then were potted in mimosa leaf mould.

2.1.3 Root initiation and rooting.

Pyke (1931) reported that the cuttings had callused and some had rooted just above the callus in three weeks when the leaves were retained. In four or five weeks, cuttings were well rooted and fit for potting. Observing on the varietal differences in the rooting behaviour of cocoa cuttings, Pyke (1933) reported that the cuttings in both Criollo and Forastero tended to fall into two groups, one with a mean rooting time of 18.9 days and the other with a mean of 39 days.

Cheesman and Spencer (1935) reported 100 per cent rooting of fan shoots in three weeks while chupons took upto 12 weeks. Bhandary and Shivashankar (1974) observed

root initiation in growth regulator treated cuttings after three weeks of planting. Wood (1978) reported that optimum conditions would lead to growth of a prolific root system within fourteen days but twentyone days was the usual duration.

2.1.4 Root system.

Differences in the nature of root system of cocoa plants resulting from rooting of cuttings have been observed by several workers. Pyke (1933) reported that there was marked dimorphism between the root systems of fan and chupon cuttings. In the fan, the characteristic type of root system in which the spread of the roots occurred at an angle between 72° and 60° to the vertical, was practically constant. The chupon exhibited a variety of root systems ranging from the vertical to the almost horizontal. In the chupon however there was always atleast one vertical root.

2.2 Budding

Cocoa is usually grown from seed though several methods of vegetative propagation are known. Budding is an easy and cheap method of clonal multiplication and has been used as such in many countries (Rosenquist, 1952; Mabey, 1964; Ascenso, 1968; Van de Burg, 1969).

2.2.1 Methods.

Patch budding had been used for budding cocoa seedlings and for top budding cocoa trees (Van Hall,1932; Burchardlt,1936).

Paredes (1949) had recommended making an inverted 'U' cut with a rectangular patch bud. Keeping (1950) also suggested a modified forkert method of budding while Rosenquist (1952) reported 56 to 82 per cent success with patch budding.

Topper (1956) developed an inverted-'T' method, a form of shield budding, which involved the use of buds upto 4 cm long taken from mature terminal shoots.

Liabeuf (1958) tried the inverted- 'T' method for the propagation of selected clones and obtained 50 to 80 per cent success after top budding chupons growing from previously cut back eight year old trees. Urquhart (1961) reported the use of shield budding on four month old cocoa seedlings. Ascenso (1968) obtained 50 to 80 per cent success with patch budding and 77 per cent with inverted-'T' method in Sao Tome. Van de Burg (1969) found that better results could be obtained by the forkert method if the flap of the rind was completely cut off from the stock.

2.2.2 Budwood preparation.

Paredes (1949) recommended preparation of budsticks eight days before their removal from the trees by cutting of the leaf blades. Keeping (1950) reported that with modified forkert method, unpetioled budwood produced 44 per cent matured plants after three months and petioled budwood 38 per cent; although the latter grew out more quickly. Giesberger and Coester (1976) described a pretreatment of cutting off the leaves and the terminal end of the branch ten days before budding; but according to them this was not effective. Ascenso (1968) also suggested that the practice of budwood preparation by cutting off the leaf blades 10 days prior to collection of budwood was not to be recommended in Sao Tome as it involved extra work and brought no significant increase in budding efficiency.

2.2.3 Cutting of rootstock.

Paredes (1949) recommended that the rootstock be decapitated about 10cm above the bud at the time of budding. Topper (1957) suggested nicking and bending over of the rootstock about 10 cm above the bud when most of the buds would grow in a fortnight.

Ascenso (1968) recommended cutting off the tape used to tie the bud after 10 to 14 days. If the budding was successful, the stock could then be nicked four inches above the union and bent down to the ground where it was fastened by pegs.

Giesberger and Coester (1976) reported that measures to induce the bud to shoot were required after the bud has taken and the bud patch has hardened off for a week, failing which the apical dominance effects of the rootstocks would inhibit the sprouting of buds. They recommended slicing the stem of the rootstock to a length of two to three cm and a depth of half the diameter of the rootstock above the bud union without breaking it. The terminal part of the rootstock could also be cut off. A month later, when the bud shoot had developed its first flush of properly hardened leaves, the rootstock could finally be cut back with a slanting cut just above the bud union.

2.2.4 Green budding.

Budding on much younger rootstock saves considerable cost and time. Topper (1956, 1957,1959) developed a technique of green budding on, three to four month-old-cocoa rootstocks. Hurov (1961, 1971) subsequently improved it and introduced it to Malaysia for budding two to four month old rubber seedlings.

Giesberger and Coester (1976) conducting glasshouse experiments on green budding tried 'T' budding and the

inverted 'U' or modified forkert method in two to six week-old seedlings. The modified forkert method was reported to give 90 to 100 per cent success. Green budding of very young rootstocks in the nurseries should result in the establishment of cocoa plantings from well grown buddings within five to six months.

MATERIALS AND METHODS

MATERIALS AND METHODS

In view of the importance of the standardisation of quality seedling selection and vegetative propagation methods in cocoa, a study on the various aspects of propagation was undertaken at the College of Horticulture from May 1978 to July 1979. The study included standardising the criteria for selecting the pods, seeds and seedlings, determination of the optimum size of polythene bags and the suitable potting medium to be used, viability of seeds in storage, the characteristics of the root, and standardisation of vegetative propagation methods. The details of the methods followed are as given below.

1. SEED PROPAGATION

1.1 Selection of Pod

Mature Forastero pods (those showing yellow colour particularly in the furrows) were harvested at monthly intervals from selected plants yielding more than 100 pods per year. Pods were collected at monthly intervals from December 1978 to April 1979. The pods were then classified into 'large', 'medium' and 'small' depending upon their size. (Plate I) Ten pods were collected in each size group during each month.

PLATE I Three classes of pods
Large, Medium and Small.

1.2 Pod Characters

In each category, the following observations of the pods were recorded. The length of the pod was measured in cm as the distance between the pedicel end and the apex of the pod. The girth at the thickest portion of the pod was measured in cm using a twine and a scale. The weight of the pods was recorded in gm. The volume of the pods was determined by the water displacement method and expressed in cc.

1.3 Seed Characters

1.3.1 Classification of seed based on the position.

The pods were then cut into three equal portions with a knife and the three portions were classified as the 'pedicel end'(1/3rd of the pod near the pedicel), the 'middle' (middle 1/3rd) and the 'distal end' (1/3rd of the pod from the distal end).

1.3.2 Number and weight of the seeds.

The seeds in each of the above groups were collected separately and the following observations were recorded.

The number of good, fully formed (hard) seeds in each group and their weight. The number of incompletely formed (soft) seeds in each group.

From the ten pods harvested for each group per month, the seeds were pooled seperately from each position. Thus for ten 'large' sized pods harvested at one month, the seeds from the 'pedicel end' were pooled together as also the seeds from the 'middle' portion and 'distal' end. Similar pooling was also done for 'medium' and 'small' sized pods.

1.4 Sowing of Seeds

1.4.1 Potting containers and media.

The pooled seeds in each category were sown in polythene bags of 23 x 15 cm lay flat size (gauge 150) containing potting medium of 1:1:1 proportion of soil sand and well decomposed farm yard manure (FYM).

1.4.2 Method of sowing.

The seeds were sown flat in the potting mixture at the rate of one per bag at one cm depth. Nine treatments were replicated three times with 30 bags in each treatment per replication. The treatments were T_1-large pedicel end, T_2-large middle, T_3-large distal end, T_4-medium pedicel end, T_5-medium middle, T_6-medium distal end, T_7-small pedicel end, T_8-small middle and T_9-small distal end.

1.5 Germination

The germination was recorded every day and the total and percentage germination were calculated.

1.6 Seedling Characters

The seedling characters such as the height, the girth and the number of leaves were recorded at fortnightly intervals starting from the 15th till the 90th day after germination. The dry weight of the shoot was recorded from the 30th day till the 90th day at monthly intervals after drying in an electric oven at 70°C for three days.

1.7 Root Characters

1.7.1 Method of study.

The roots were studied after cutting and removing the polythene bags and placing the ball of earth in the water and carefully washing out the soil.

1.7.2 Length of tap root, number and length of laterals.

The length of the tap root and the longest lateral root and the number of lateral roots were recorded. The recording was done at monthly intervals starting from 30 till 90 days after germination. Data were recorded separately from five sets of seedlings sown in December 1978, January, February, March and April 1979.

1.7.3 Dry weight.

The dry weight of the root was recorded from the 30th day till the 90th day at monthly intervals.

1.8 Size of Containers and Potting Medium

1.8.1 Size of containers.

Another experiment was carried out to determine the optimum size of polythene bags for growing the seedlings for three months. Three sizes of polythene bags namely, 23 x 15 cm (T_1), 25 x 18 cm (T_2),and 30 x 20 cm (T_3) were used. For each size, fifty bags were filled with standard (1:1:1) potting mixture and well developed seeds were sown at the rate of one seed per bag. The trial was repeated thrice in the months of December 1978, February 1979 and March 1979. Observations as mentioned earlier regarding the shoot and root characters were recorded.

1.8.2 Proportion of potting medium.

In order to determine the best economical potting mixture for optimum health growth of cocoa seedlings, another experiment was conducted. The treatments were T_1- soil, T_2-soil, sand and FYM (1:1:1) and T_3-soil, sand and FYM (1:1:2).

Fifty sound seeds were sown per treatment and the trial was repeated thrice in December 1978, February 1979 and March 1979. All the observations mentioned previously were recorded.

1.9 Studies on the Viability of Seeds

To test the viability of seeds after storage, a trial was undertaken with the following treatments:

i) storing the pods in the room, extracting the seeds and sowing them on the 3rd, 6th, 9th and 12th day after harvest.

ii) storing the pods in the refrigrator and sowing the extracted seeds on the 3rd, 6th, 9th and 12th day after harvest.

iii) extracting the seeds on the same day of harvest, keeping them in polythene bags under room temperature and sowing them on the 3rd, 6th, 9th and 12th day after extraction.

iv) as in (iii), but keeping the polythene bags in the refrigerator and sowing the seeds on the 3rd, 6th, 9th and 12th day after extraction.

Two pods were used for each treatment and the seeds were sown in polythene bags. The number of seeds germinated were recorded.

1.10 Root Studies

In order to study the characteristics of roots at various ages of seedlings, another experiment was carried out.

Root characters were studied for the following age groups of seedlings: 15, 30, 60, 90, 180 and 270 days after germination. Twenty seedlings were studied for each age group.

The length of the tap root and longest lateral, the number of laterals, as well as the dry weight of the root were recorded for each seedling and the mean was worked out.

2. VEGETATIVE PROPAGATION

In order to standardise the vegetative propagation methods, rooting of cuttings and different methods of budding were tried as detailed below.

2.1 Rooted Cuttings

2.1.1 Preparation of cuttings.

From selected three year old Forastero trees, semi hardwood cuttings were taken from mature fan branches of current season growth. The cuttings taken had fully hardened leaves. The bark was brown on the anterior side and green on the posterior side. Three to four leaves were retained with 1/3rd of the lamina (Plate II). The cuttings were taken early in the morning and put in buckets containing water till they were treated with growth regulators and planted.

PLATE II A semi-hard wood cutting prepared for rooting.

2.1.2 Treatment with growth regulators.

The growth regulators tried were indole-3-acetic acid (IAA), alpha-naphthalene acetic acid (NAA), indole-3-butyric acid (IBA) and a mixture of alpha-naphthalene acetic acid and indole-3-butyric acid at concentrations of 2000,4000,6000 and 8000 ppm in 50 per cent ethyl alcohol. The 'quick dip' method was used at four different dip durations of 10, 20, 30, and 60 seconds. There were 65 treatments including control, in which the cuttings were not treated with any growth regulator. Ten cuttings were used for each treatment per replication and there were three replications.

2.1.3 Method of planting cuttings.

The cuttings were taken to the nursery and given a fresh cut at the base. The water at the base of the cutting was blotted out and then the cuttings were dipped in the specific solution of growth regulators for the required time. The cuttings were slightly shaken to remove any excess growth regulator solution and planted in previously watered sand beds raised to a height of 12cm.

2.1.4 Methods of covering cuttings.

Two methods were used for covering the cuttings. After thorough watering, one set of cuttings was covered with a polythene sheet following McKelvie's method(Plate III). The edges all around were sealed off with wet clay.

PLATE III Polythene sheet method of rooting cuttings.

the cuttings were watered once in three days by removing the polythene sheet and later replacing the sheet as before. The clay used for plastering the edges was also kept wet to prevent cracking.

In the second method, a wooden frame 2.0x1.0x0.5m in size was contructed and covered with polythene sheet (Plate IV). This frame was placed over the bed of cuttings which was first watered. The edges were sealed as before. The sand bed was watered only when needed. However, to maintain humidity, sprays of water were given once a week inside the frame by inserting the nozzle of a sprayer.

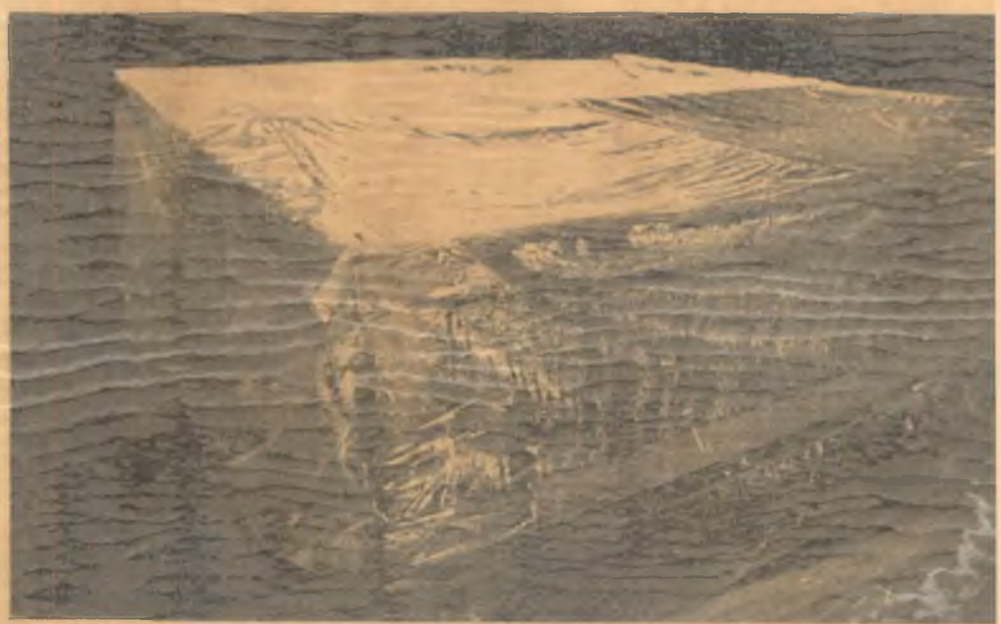
The number of cuttings rooted, the number of roots per cutting and their average length were recorded after 60 days.

2.2 Budding

2.2.1 Methods of budding.

Budding was done on cocoa seedlings of 7 to 11 months age. The methods tried were patch, forkert, 'T', and 'inverted-T'. Only the standard methods of budding were adopted except in the case of forkert budding where half the flap was cut and removed in the beginning itself.

PLATE IV Mist chamber method of rooting cuttings.



2.2.2 Selection and preparation of bud wood.

Budwood was taken from selected mother trees. Recently matured fan or chupon branches of approximately the same girth as the rootstock, growing vigorously and containing several good buds were used as budwood. The buds in the upper end were discarded. Pre curing of the budwood was done by defoliating the twigs 10 days in advance. The budwood was collected just before the budding operations and the basal ends of the budwood twigs were dipped in water till it was used for budding to avoid desiccation.

2.2.3 Budding technique.

The bud was inserted into the rootstock just below the cotyledonary mark. Polythene tape was used to completely cover the bud union from about two cm above the bud patch to two cm below (Plate V). The tape was carefully cut after 15 days. A month after budding, a cut was given to the rootstock above the bud union to about half the thickness of the stock first horizontally and then vertically extending about four to seven cm upwards(Plate VI). After two months of scion growth when the leaves had hardened, the stock was cut back immediately above the bud union. Till the stock was cut, the scion growth was supported with twigs to prevent damage.

PLATE V Different stages in budding

PLATE VI The cut given to the root stock a month after budding.

2.2.4 Green budding.

Juvenile cocoa seedlings, two to four months old, were used for green budding. Budwood was taken from chupon or fan branches which were young and green or greenish brown. The four methods tried for older root stocks were also tried in green budding.

3. STATISTICAL ANALYSIS

The data on the different characters studied were subjected to statistical analysis, following the methods suggested by Snedecor and Cochran (1967). Transformations were done wherever needed and the data analysed by the analysis of variance technique. Significant results were compared after finding out the critical differences.

RESULTS

RESULTS

1. SEED PROPAGATION

Seed propagation studies were initiated to standardise the criteria for selecting the pods, seeds and seedlings in cocoa. The results of the study are presented below. The analysis of variance tables for the different characters are given in Appendix

The first phase of the study included the assessment of variation among the 'large', 'medium' and 'small' pods in the volume, weight, number and weight of sound seeds as well as in the mean weight of a sound seed. The data on the above characters are presented in Table 1.

1.1 Pod Characters

1.1.1 Volume of pod.

The volume of the pods, determined by the displacement method, was found to vary with the different classes and variation was also noticed within the classes during the different months. The large pods recorded a mean volume of 615 cc during December and February while the corresponding figures for January, March and April were 391, 466 and 497cc respectively. The medium sized pods had volumes of 445, 284, 407, 345 and 358 cc in December, January, February, March and April, respectively. The small pods recorded

Table 1. Characters of the three classes of Cocoa pods in different months.

(Mean values)

Month	Size of pod.	No.of pods studied.	Length (cm)	Girth (cm)	Volume (c.c.)	Weight (gm)	No.of seeds	No.of sound seeds	Weight of sound seeds (gm)	Average weight of a seed. (gm)
December 1978	Large	10	20.6	28.08	615	617	36	34.4	93.27	2.71
	Medium	10	16.80	26.71	445	428	34.5	34.1	83.6	2.45
	Small	10	13.85	24.65	354	294	36.4	34.3	75.5	2.20
January 1979	Large	10	19.73	23.48	391	270	30	29	76.8	2.65
	Medium	10	16.12	23.24	284	174	35.9	34.1	68.6	2.01
	Small	10	14.04	22.73	253	152	34.7	33.3	62.2	1.87
February 1979	Large	10	18.84	27.92	615	475	42	40.5	124.3	3.07
	Medium	10	15.48	25.44	407	308	35.6	35.2	104.7	2.97
	Small	10	13.33	23.41	276	192	38.2	36.7	76.95	2.10
March 1979	Large	10	16.91	26.68	466	428	40.1	39.3	115.3	2.93
	Medium	10	16.31	23.55	345	304	40.5	37.3	90.8	2.60
	Small	10	12.3	22.42	268	236	37	35.9	91.8	2.56
April 1979	Large	10	18.45	27.41	497	535.41	40.6	39.5	119.15	3.02
	Medium	10	17.31	25.22	358	356	41.2	39.5	94.8	2.40
	Small	10	13.52	23.20	228	272	37	35.9	84.05	2.34

354 cc and 276 cc in December and February while in the months of January, March and April the volumes were 253, 268 and 228 cc, respectively.

Thus it can be seen from the data presented that the volume varied among the classes of pods and also within each class in the different months. Regarding the different months, the pods harvested in December and February had comparitively higher volume.

1.1.2 Weight of pod.

The large pods had a mean weight of 617 g and 535.41 g in December and April while in the months of January, February and March the weights were 270 g, 475 g and 428 g, respectively.

The medium sized pods also had their highest mean weights in December and April when the weights were 428 g and 356 g. The corresponding figures for January, February and March were 174 g, 308 g and 304 g, respectively.

The small pods had a mean weight of 294 g in December and 272 g in April while in January, February and March the weights were 152 g, 192 g and 236 g, respectively.

It can thus be seen that the weight of the pods also varied among the three classes of pods and also within each class in the different months. Among the months, December and April recorded the highest weight in all the classes.

1.2 Seed Characters

1.2.1 Number of seeds.

In December, the mean number of seeds was 36 in large pods, 34.5 in medium pods and 36.4 in small pods. This indicates that there was not much variation in the number of seeds among the three classes of pods. In January, the number of seeds was 30 for large pods, 35.9 for medium pods and 34.7 for small pods while in February the corresponding numbers were 42, 35.6 and 38.2. In March, the variation was even less with 40.1 for large, 40.5 for medium and 37 for small pods. The same trend was reflected in April also where the figures were 40.6 for large, 41.2 for medium and 37 for small pods.

The number of seeds did not show much variation among the three classes of pods as also between the classes in the different months. However, comparing the different months, the number of seeds were higher in pods harvested in February, March and April. The mean number of seeds per pod taking all size groups together varied between 30 and 42.

1.2.2 Weight of sound seeds.

The sound seeds from large pods had a mean weight of 93.27 g in December, 76.8 g in January, 124.3 g in February, 115.3 g in March and 119.15 g in April. The corresponding figures for medium pods were 83.6 g, 68.6 g, 104.7 g, 96.8 g and 94.8 g while for small pods the figures were

75.50g, 62.20g, 76.95 g, 91.80g and 84.05 g, respectively.

The weight of the sound seeds in the different classes of pods varied in the different months. The weights were highest in the months of February, March and April for sound seeds from all the classes of pods.

1.2.3 Mean weight of a sound seed.

The mean weight of a sound seed from large pods varied from 3.07 g in February to 2.65 in January while in the months of December, March and April the mean weights were 2.71 g, 2.93 g and 3.02 g respectively. The medium pods gave sound seeds weighing from 2.97 g in February to 2.01 in January while in the months of December, March and April the weights were 2.45 g, 2.60 g and 2.40 g, respectively. The variation in mean weight of a sound seed from small pods was from 2.56 g in March to 1.80 g in January. The corresponding weights in the months of December, February and April were 2.20 g, 2.10 g and 2.34g.

There was wide variation in the mean weight of a seed among the three classes of pods. The seeds from the large pods had the highest weight followed by the seeds from the medium pods while the seeds in the small pods had the lowest weight. Considering all the size groups together, the mean weight of a sound seed varied between 1.87 and 3.07 g. The mean weight of a seed from large and medium pods was highest in February followed by March. Seeds from small pods weighed highest in March.

Thus from a study of various characters of the pods, it is clear that there was wide variation in the volume and the weight among the three classes of pods and also in the different months of harvest within each class. The volume and weight were highest obviously for large pods. The volume was highest in the pods harvested in December and February while the mean weight was highest in December and April. There was not much variation in the number of seeds among the three classes while among the different months the number was highest in the case of pods harvested in February, March and April. Regarding the weight of sound seeds the three classes differed in their weight suggesting differences in the average weight of individual seeds. The mean weight of a seed was highest for large pods and lowest for small pods. The mean total weight of sound seeds in a pod as well as the mean weight of a seed was highest in February, March and April.

In the second phase of the study, the germination, vegetative growth, root growth and accumulation of dry weight were studied. The large, medium and small pods were divided into three sections namely, the pedicel end, the middle portion and the distal end. Monthly sowing of the seeds from these position groups in the three size groups was done separately and the germination behaviour assessed.

For analysing the vegetative growth, root growth and dry matter accumulation the identity of position groups and size groups was also maintained.

1.3 Germination

1.3.1 Number of days for germination.

The germination was found to start on the eighth day and continue upto the tenth day after sowing, for all the treatments.

1.3.2 Percentage of germination.

The mean percentage of germination for the five monthly sowings are presented in Table 2.

No significant difference in respect of the percentage of germination among the different treatments was observed in any of the monthly sowings.

For the December sowing, the percentage of germination was highest for T_4 (89.6) followed by T_7 (89.0) and T_1(88.9) The lowest percentage of germination was for T_8(64.3). The percentage of germination was highest for T_7 (87.0) followed by T_6 (87.0) and T_4 (86.0) during January sowing. The lowest percentage was for T_3 (69.5). The highest percentage of germination in the February sowing was for T_8 (98.8) followed by T_5 (98.4) and T_2 (95.6). The lowest percentage was for T_1 (69.4). The maximum percentage of germination during March sowing was for T_1 (99.2) followed by T_2(98.5),

Table 2. Percentage of Germination of Cocoa seeds in different months
(Mean values)

Treatments	December	January	February	March	April
T_1-LP	88.9 (70.53)*	71.8 (57.91)	69.4 (56.41)	99.24 (85)	90.4 (71.96)
T_2-LM	82.6 (65.38)	75.6 (60.46)	95.6 (77.87)	98.5 (83.02)	81.3 (64.4)
T_3-LD	80.3 (63.63)	69.5 (56.5)	85.3 (67.5)	86.5 (68.43)	83 (65.69)
T_4-MP	89.6 (71.15)	85 (68.02)	75 (60)	94.3 (76.15)	71 (57.4)
T_5-MM	71.6 (57.8)	75.3 (60.18)	98.4 (82.87)	97.6 (81.15)	81.4 (64.42)
T_6-MD	75.1 (60.07)	87 (68.85)	71.7 (57.87)	95.9 (77.71)	80 (63.44)
T_7-SP	89 (70.76)	87.9 (69.59)	85.8 (67.88)	91.2 (72.71)	66.9 (54.89)
T_8-SM	64.3 (53.33)	84.6 (66.92)	90.8 (83.85)	97.2 (80.36)	81.8 (64.75)
T_9-SD	64.6 (53.47)	76 (60.65)	90.2 (71.8)	89.1 (70.74)	61.3 (51.55)
F - Value	0.308^{NS}	0.175^{NS}	0.285^{NS}	0.635^{NS}	0.460^{NS}
C.D-(0.05)	18.35	31.49	25.02	18.54	24.45

NS Not significant
* The figures in parenthesis are angular transformed ones.

T_4 (97.6), T_5 (95.5) and T_4 (94.3). The minimum percentage of germination was for T_3(86.5). The highest percentage of germination during April sowing was recorded for T_1(90.4) followed by T_3 (83.0) and T_3 (81.8). The lowest was for T_9(61.3).

The results clearly indicate that neither the size of the pod nor the position of the seed inside the pod (pedicel end, middle and distal end) had any significant influence on the germination percentage. Hence, pods of any size and all the sound seeds in a pod can be utilised for propagation. Among the different months, disregarding the classes of pods and the position of seeds in the pods, the germination percentage was highest in March (94.35), followed by February (85.58), January (79.29), December (78.44) and April (77.46). This indicated that the pods harvested in February and March will give higher germination and those harvested in December, January and April should be avoided for propagation purposes.

1.4 Growth Studies

1.4.1 December sowing.

(i) Vegetative growth.

The data on the growth parameters such as the height, the girth and the number of leaves produced under varying sizes of pods and position of seeds are presented in Table 3a.

Table 3a. Shoot growth parameters of Cocoa seedlings at various intervals sown in different months. December sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves
T_1-LP	15.74	1.34	3.6	18.54	1.36	4.27	20.01	1.71	6.47
T_2-LM	11.54	1.34	3.53	15.46	1.36	4.4	17.07	1.66	7.07
T_3-LD	13.74	1.34	4.45	16.46	1.4	5.6	17.21	1.76	7.13
T_4-MP	10.63	1.21	4.07	11.59	1.33	5.07	16.60	1.37	7
T_5-MM	11.41	1.23	4.07	11.52	1.29	5.33	16.03	1.4	6.6
T_6-MD	15.06	1.21	4.07	15.74	1.24	4.73	17.11	1.39	5.4
T_7-SP	14.98	1.13	3.93	19.60	1.26	4.27	21.01	1.65	6.2
T_8-SM	17.04	1.2	4.27	20.91	1.40	4.73	21.95	1.58	6.13
T_9-SD	14.20	1.21	4.4	15.12	1.33	4.8	16.56	1.50	6.6
F-Value	3.54*	0.05^{NS}	1.61^{NS}	9.92**	0.71^{NS}	1.59^{NS}	4.32*	0.65^{NS}	9.87**
CD-(0.05)	3.77	0.30	0.66	2.74	0.20	1.2	2.74	0.21	0.62

NS Not significant.
* Significant at 5% level.
** Significant at 1% level.

Table 3a. Continued.

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves
T_1-LP	22.53	1.85	7.86	30.73	2.05	10.66	43.40	2.29	12.6
T_2-LM	22	1.88	8.96	24.19	2.05	9.73	29.63	2.22	12.2
T_3-LD	19.33	1.80	9.16	27.42	1.98	11.26	27.42	1.98	11.26
T_4-MP	17.04	1.45	8.03	23.03	1.8	10.73	28.56	1.91	12.26
T_5-MM	16.68	1.65	8.2	33.60	2.05	11.16	33.77	2.05	11.16
T_6-MD	20.79	1.75	7.06	24.96	2.26	10.4	28.38	2.26	10.4
T_7-SP	22.96	1.82	9.93	26.86	1.95	10.06	38.93	1.95	11.2
T_8-SM	24.12	1.85	7.53	25.22	2.03	9.93	30.20	2.08	10.8
T_9-SD	18.72	1.67	8.26	20.13	1.70	10	25.16	2.03	10.46
F-Value	2.38^{NS}	5.86^{**}	13.42^{**}	4.93^{**}	1.21^{NS}	1.05^{NS}	0.88^{NS}	1.21^{NS}	0.38^{NS}
CD(0.05)	5.19	0.14	0.85	6.34	0.52	1.69	16.88	0.51	1.66

NS Not significant.
** Significant at 1% level.

The height of the seedlings varied significantly at 5% per cent level on the 15th and 45th days and at 1 per cent level on the 30th and 75th days. There was no significant variation at the 60th and 90th days.

There was significant variation at 1 per cent level in the girth of the seedlings at the 60th day only and in the number of leaves at the 45th and 60th days.

On the 15th day after germination, the maximum height was 17.04 cm for T_8 which was significantly higher than those for T_2, T_5 and T_4 and on par with those of T_1, T_6, T_7, T_9 and T_3. The minimum height was recorded for T_4(10.63 cm). The girth varied between 1.13 cm for T_7 and 1.34 cm for T_1, T_2 and T_3 while the number of leaves ranged from 3.53 for T_2 to 4.45 for T_3.

On the 30th day, the height for T_8 (20.91 cm) was significantly higher; but this was on a par with the figures for T_7 and T_1. The minimum height was recorded for T_5 (11.5 cm). The girth during the period varied between 1.24 cm for T_6 to 1.4 cm for T_3 and T_8. The number of leaves varied between 4.27 for T_1 and T_7 and 5.6 for T_3.

On the 45th day after germination, the height for T_8 (21.95 cm) was significantly higher. T_8 was on par with T_7 and T_1. The lowest height at this period was recorded for T_5 (16.03 cm). The girth ranged from 1.37 cm for T_4 to 1.76 cm for T_3. The number of leaves was significantly

higher for T_3 (7.13) which was however on par with T_2, T_4, T_5 and T_9. The number of leaves was lowest for T_6 (5.4).

On the 60th day, the height varied from 16.68 cm for T_5 to 24.12 cm for T_8. The girth for T_2 (1.88 cm) was significantly greater, though on par with those for T_8, T_1, T_2, T_3 and T_6. The lowest girth was for T_4 (1.45 cm). The number of leaves for T_7 (9.93) was significantly greater; but this was on par with the data for T_3. The lowest number of leaves recorded was for T_6 (7.06).

On the 75th day, the height for T_5 (33.68 cm) was significantly higher. T_5 was on par with T_1 and T_3. The height for T_9 (20.13 cm) was the minimum recorded. The girth at this interval ranged from 1.7 cm (T_9) to 2.26 cm (T_6) while the number of leaves varied from 9.73 (T_2) to 11.27(T_3).

On the 90th day after germination, the height of the seedlings varied from 25.16 cm (T_9) to 43.4 cm (T_1) while the girth varied from1.81 cm (T_4) to 2.29 cm (T_1). The number of leaves at this stage ranged from 10.4 (T_6) to 12.6 (T_1)

The data on the height, girth and number of seedlings for the different pod sizes are presented in Table 3b.

There was significant difference in the height of the seedlings on the 15th and 60th day after germination at 5 per cent level and on the 30th and 45th days at one per cent level. At these intervals, the height for the

Table 3b. Shoot growth parameters of Cocoa seedlings at various intervals sown in different months. December sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves.
Large	13.67	1.34	3.86	16.82	1.38	4.7	18.10	1.71	6.00
Medium	12.37	1.22	4.06	12.05	1.39	5.04	16.61	1.38	6.35
Small	15.40	1.10	4.2	18.54	1.33	4.6	19.84	1.58	6.31
F-Value	4.32*	2.03NS	1.79NS	28.78**	1.29NS	0.93NS	9.19**	14.7**	7.46**
CD (0.05)	2.17	0.17	0.37	1.58	0.11	0.69	1.38	0.12	0.35

NS Not significant.
* Significant at 5% level.
** Significant at 1% level.

Table 3b. Continued

Days after germination	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves
Large	21.28	1.84	8.66	27.44	2.03	10.95	33.48	2.16	12.02
Medium	10.17	1.61	7.76	27.22	2.04	10.76	30.24	2.06	11.27
Small	21.93	1.78	8.57	24.07	1.89	10.00	28.16	2.01	10.82
F-Value	3.97*	16.54**	0.93**	2.23^{NS}	0.62^{NS}	1.44^{NS}	0.68^{NS}	0.60^{NS}	3.38
CD (0.05)	2.99	0.08	0.49	3.66	0.30	0.97	9.74	0.29	0.96

NS Not significant
* Significant at 5% level
** Significant at 1% level.

seedlings from small pods was significantly higher. But on the 75th and 90th days there was no significant variation. The girth was significantly different on the 45th and 60th days only when the girth of seedlings from large pods was significantly higher. Here also, by the 75th and 90th days there was no significant variation. The same trend was reflected for the number of leaves produced as well. Therefore, it can be seen that the benefits of growth were not significant when the seedlings are three months old irrespective of the size of the fruit.

The data on the height, girth and number of leaves for the three positions of seed (pedicel end, middle portion and distal end) are presented in Table 3c. There was significant difference in the height of the seedlings only on the 45th day when the height was significantly higher for 'pedicel end' which was on par with 'middle'. There was no significant difference in the girth and number of leaves produced at any of the intervals.

Therefore, the data indicate no significant difference in growth characters when the seedlings are three months old irrespective of the position of the seed within the pod.

(ii) Root growth.

The data on the length of the tap root, the longest lateral root and the number of lateral roots are given in Table 4a.

Table 3c. Shoot growth parameters of Cocoa seedlings at various intervals sown in different months. December sowing.

Days after germination	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves.
Radicel end.	13.78	1.22	3.86	16.58	1.33	4.53	19.23	1.58	6.55
Middle	13.33	1.26	3.95	15.96	1.35	4.32	18.35	1.54	6.6
Distal end.	14.33	1.25	4.30	15.78	1.32	5.04	16.96	1.55	6.37
F-Value	0.47^{NS}	0.08^{NS}	3.3^{NS}	0.61^{NS}	0.13^{NS}	1.2^{NS}	4.61*	0.17^{NS}	5.96
CD (0.05)	2.17	0.17	0.37	1.58	0.11	0.69	1.58	0.12	0.35

NS Not significant.

* Significant at 5% level.

Table 3c. Continued

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves.
Pedicel end.	20.84	1.71	8.61	26.87	1.93	10.48	33.63	2.01	12.02
Middle	20.93	1.79	8.23	27.70	2.04	10.27	31.20	2.11	11.38
Distal End.	19.61	1.74	8.16	24.17	1.98	10.55	26.90	2.09	10.71
F-Value	0.53 NS	2.23 NS	2.09 NS	2.23 NS	0.30 NS	0.19 NS	1.04 NS	0.24 NS	4.10*
CD(0.05)	2.99	0.08	0.49	3.66	0.30	0.97	9.74	0.29	0.96

NS Not Significant
* Significant at 5% level.

Table 4a. Root growth parameters of Cocoa seedlings at various intervals sown in different months. December sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No. of lateral roots.
T_1-LD	11.95	2.93	21.67	12.41	6.27	72	23.00	7.25	147.6
T_2-LH	11.24	3.13	20.6	12.71	4.31	78.66	21.11	10.21	99.66
T_3-LM	12.17	3.47	24.8	14.20	5.25	79.33	19.67	9.53	120
T_4-MD	9.7	3.73	25.93	12.51	4.7	72.33	14.44	7.16	106.66
T_5-MH	12.66	2.77	20.47	13.61	4.8	82.66	13.92	8.99	130.06
T_6-MM	13.51	2.67	21.67	15	4	71.66	10.54	6.43	137.66
T_7-SD	12.79	3.49	22.87	17	5.09	61.66	23.44	8.47	64.33
T_8-SH	13.42	3.79	23.47	15.3	6.56	58	18.98	5.13	67.06
T_9-SM	12.02	2.67	21.13	16.35	3.98	51.4	16.98	7.98	71.33
F-Value	3.18*	2.27^{NS}	1.32^{NS}	2.13^{NS}	23.94**	0.35^{NS}	1.21^{NS}	1.63^{NS}	1.87^{NS}
CD(0.05)	2.25	1.08	5.77	1.82	0.617	26.30	7.53	3.63	42.4

NS Not significant.
* Significant at 5% level.
** Significant at 1% level.

The length of the tap root showed significant variation only at the 30th day while there was significant variation in the length of the longest lateral root at the 60th day only. There was no significant variation in the number of lateral roots at any of the intervals. On the 30th day the length of the tap root was maximum for T_6 (13.51 cm) and minimum for T_4 (9.7 cm). T_6 was on par with T_8, T_7, T_5, T_3, T_9 and T_1. The length of the longest lateral root varied from 2.67 cm (T_5 and T_9) to 3.79 (T_8) while the number of lateral roots ranged from 20.6 (T_2) to 25.93 (T_4).

On the 60th day the length of the tap root varied from 12.41 cm (T_1) to 17 cm (T_7). The length of the longest lateral root was significantly higher for T_8(6.55cm) which was on par with T_1. The lowest value was obtained for T_9 (3.93 cm). The number of lateral roots for this period varied from 51.4 (T_9) to 82.66(T_5). The length of the tap root ranged from 13.92 cm (T_5) to 23.44 cm (T_7) on the 90th day. The length of the longest lateral root varied from 5.13 cm (T_8) to 10.21 cm (T_2) while the number of lateral roots varied from 64.33 (T_7) to 147.66 (T_1).

Considering the effect of pod size on the root growth (Table 4b) there was significant difference in the length of the tap root at 1 per cent level on the 60th day when the length was significantly higher for 'small' and at 5 per cent

Table 4b. Root growth parameters of Cocoa seedlings at various intervals sown in different months. December sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.
Large	11.78	3.17	22.35	13.10	5.27	76.66	21.26	8.99	122.44
Medium	11.96	3.05	23.35	13.70	4.5	75.98	15.63	7.54	124.8
Small	12.74	3.31	22.48	16.21	5.18	57.02	19.80	6.53	67.57
F-Value	1.36^{NS}	0.39^{NS}	0.23^{NS}	21.61**	12.5**	4.66*	3.98*	3.1^{NS}	15.43*
CD (0.05)	1.30	0.62	3.33	1.05	0.36	15.18	4.34	2.09	24.48

NS Not significant

* Significant at 5% level

** Significant at 1% level.

on the 90th day when the length was significantly higher for 'large'. The length of the longest lateral root showed significant variation only on the 60th day, the length being significantly higher for 'large' which was on par with 'small'. The number of lateral roots varied significantly on the 60th day, the number being significantly higher for 'large' (on par with 'medium') and on the 90th day, the number being significantly higher for 'medium' which was on par with 'large'.

Taking into account of the position of the seed alone (Table 4c) the length of the tap root varied significantly only on the 60th day when the length was significantly higher for 'distal end'. The length of the longest lateral root varied significantly only on the 60th and when the length was significantly higher for 'pedicel end'. There was no significant variation in the number of lateral roots at any of the intervals.

(iii) Dry weight.

The data on the mean dry weight of the shoot, root and the total dry weight are presented in Table 5a.

Significant variation in the dry weight of the shoot was obtained on the 60th day only while for the dry weight of the root as well as the total dry weight there was no significant variation at any of the intervals.

Table 4c. Root growth parameters of various intervals sown in different months. December sowing.

Days after germination	30th day			60th day			90th day		
Treatments	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of later-al roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of later-al roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of late-ral roots.
Pedicel end.	11.48	3.38	23.48	13.97	5.35	68.66	20.29	6.95	106.22
Middle	12.44	3.23	22.17	13.87	5.21	73.11	18.00	8.11	98.93
Distal end	12.57	2.93	22.53	15.18	4.39	67.46	18.39	7.99	108.66
F-Value	1.84^{NS}	1.19^{NS}	0.36^{NS}	4.22*	18.83**	0.33^{NS}	0.70^{NS}	0.81^{NS}	0.44^{NS}
CD(0.05)	1.30	0.62	3.33	1.05	0.36	15.18	4.34	2.09	24.49

NS Not significant.
* Significant at 5% level.
** Significant at 1% level.

Table 5a. Dry weight of Cocoa seedlings at various intervals sown in different months. December sowing

Days after germination.	30th			60th			90th		
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
T_1-LP	906	249.33	1155.33	1007.33	307.33	1314.66	2751.66	425.16	3176.83
T_2-LM	1144	265.66	1409.66	1568	354	1922.00	2946.66	428	3374.66
T_3-LD	720.66	200	920. 66	1247	316.33	1563.33	3100	472	3572.00
T_4-MP	850	277.66	1127.66	1016	385.33	1401.33	2510	410	3920.00
T_5-MM	803.33	252.66	1056.00	1126	290	1416.00	3033.33	513.66	3552.00
T_6-MD	650.66	223.66	832.33	1046.66	294.66	1341.33	2766.66	392.66	3159.33
T_7-SP	726.66	256.66	933.33	1123	346	1469.00	2350	413.33	2763.33
T_8-SM	839.66	269.33	1109.00	1194	362.66	1556.66	2540	386	2926.00
T_9-SD	634	243.66	877.66	1084	333.00	1417.00	2260	372.66	2632.66
F-Value	0.99^{NS}	0.21^{NS}	0.87^{NS}	4.8**	0.94^{NS}	3.49*	0.284^{NS}	0.85^{NS}	0.36^{NS}
CD (0.05)	257.97	102.92	321.03	185.57	117.44	257.71	894.1	150.57	955.29

NS Not significant.
* Significant at 5% level
** Significant at 1% level.

The dry weight of the shoot ranged from 634 mg (T_9) to 1144 mg (T_2) while that of the root varied from 200 mg (T_3) to 277.66 mg (T_4). The total dry weight for the same period varied from 877.66 mg (T_9) to 1409.66 mg (T_2). On the 60th day the dry weight of the shoot was significantly higher for T_2 (1569 mg). The lowest weight recorded was for T_1 (1007.33 mg). The dry weight of the root varied from 290 mg (T_5) to 362.66 mg (T_8) while the total dry weight varied from 1314.66 mg (T_1) to 1922 mg (T_2). On the 90th day the dry weight of the shoot ranged from 2260 mg (T_9) to 3033.33 mg (T_5) while that of the root ranged from 372.66mg (T_9) to 518.66 mg (T_5). The total dry weight for the same period varied from 2632.66 mg (T_9) to 3572 mg (T_3).

Considering effect of the pod size alone (Table 5_b) the dry weight of the shoot showed significant variation among the pod sizes on the 30th and 60th days when the weight for 'large' was significantly higher. The dry weight of the root did not show any significant variation at any of the intervals while the total dry weight showed significant variation only on the 60th day, the weight for 'large' being significantly higher.

Taking into account the effect of the position of the seed (Table 5c) the dry weight of the shoot was significantly different on the 30th day, and 60th day, the

Table 5b. Dry weight of Cocoa seedlings at various intervals sown in different months. December sowing.

Days after germination	30th			60th			90th		
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
Large	923.55	238.33	1161.88	1274.11	325.88	1600.00	2932.78	441.72	3374.50
Medium	770.66	251.33	1022.00	1062.89	323.33	1386.22	2770.00	440.44	3210.44
Small	733.11	256.55	989.66	1133.66	347.22	1430.88	2383.30	390.66	2774.00
F-Value	4.04*	0.22^{NS}	2.15^{NS}	8.9 **	0.33^{NS}	4.57*	2.7^{NS}	0.39^{NS}	2.62^{NS}
CD(0.05)	148.96	59.42	185.35	107.14	67.80	148.79	510.43	91.55	560.85

NS Not significant.
* Significant at 5% level.
** Significant at 1% level.

Table 5c. Dry weight of Cocoa seedlings at various intervals sown in different months. December sowing.

Days after germination	30th			60th			90th		
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
Pedicel end	827.55	261.22	1088.77	1048.78	346.22	1395.00	2537.22	416.16	2953.38
Middle	933.66	262.55	1191.22	1296.00	335.55	1631.55	2840.00	444.22	3284.22
Distal end	671.11	222.44	893.55	1125.89	314.66	1440.55	2708.89	412.44	3121.33
F-Value	6.7**	1.29^{NS}	5.97*	12.3**	0.49^{NS}	6.28**	0.76^{NS}	0.31^{NS}	0.74^{NS}
CD(0.05)	148.94	59.42	135.35	107.14	67.80	143.79	510.43	91.55	583.85

NS Not significant.
* Significant at 5% level.
** Significant at 1% level.

weight for 'medium' being significantly higher, while there was no significant difference in the dry weight of the root at any of the intervals. The total dry weight was significantly higher for 'medium' on 30th and 60th day.

1.4.2 January sowing.

(i) Vegetative growth.

The data on the height, girth and number of leaves of the seedlings are presented in Table 6a.

There was no significant difference in the height, girth and the number of leaves produced in the seedlings at any of the intervals of recording. The height of the seedlings varied between 12.87 cm (T_2) and 16.59 cm (T_4) on the 15th day after germination. The girth during the period varied between 1.21 cm (T_9) and 1.46 cm (T_2) while the number of leaves was minimum in T_7 (3.73) and maximum in T_8 (4.13).

On the 30th day the height of the seedlings varied between 15.68 cm (T_2) and 18.29 cm (T_5) while the girth varied from 1.48 cm (T_1 and T_7) to 1.55 cm (T_3). The number of leaves produced ranged from 4.27 (T_6) to 5.7(T_2). On the 45th day after germination the maximum height was 19.01 cm (T_6) and the minimum 16.26 cm (T_9). The girth for the period ranged from 1.52 cm (T_9) to 1.63 cm (T_1) and the number of leaves from 6.87 (T_1) to 8 (T_2).

Table 6a. Shoot growth parameters of cocoa seedlings at various intervals sown in different months. January sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves	Height (cm)	Girth (cm)	No.of leaves.
T_1-LP	13.89	1.38	4	15.85	1.48	5	17.33	1.63	6.87
T_2-LM	12.87	1.46	3.93	15.68	1.52	5.7	17.28	1.58	8
T_3-LD	14.87	1.39	3.8	16.88	1.55	4.6	16.88	1.56	7.13
T_4-MP	16.59	1.38	3.8	19.02	1.6	5.27	18.26	1.6	7.07
T_5-MM	15.22	1.38	4	18.29	1.52	4.6	18.92	1.59	7.3
T_6-MD	14.1	1.31	3.93	18.08	1.51	4.27	19.01	1.58	6.97
T_7-SP	13.43	1.25	3.73	17.12	1.48	5.07	17.14	1.50	7.27
T_8-SM	14.33	1.34	4.13	16.88	1.53	5.13	18.40	1.56	7.6
T_9-SD	13.07	1.21	3.87	15.99	1.51	5	16.26	1.52	7.33
F-Value	1.93^{NS}	0.22^{NS}	0.416^{NS}	0.32^{NS}	0.83^{NS}	1.75^{NS}	0.47^{NS}	0.69^{NS}	0.92^{NS}
CD(0.05)	2.53	0.18	0.602	3.41	0.14	0.876	2.79	0.16	0.78

NS Not significant.

Table 6a. Continued

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves
T_1-LP	19.77	1.66	8.8	20.91	1.69	9.4	21.25	1.70	9.6
T_2-LM	17.33	1.55	9.66	20.34	1.66	10.4	21.37	1.70	12.13
T_3-LD	21.12	1.64	9.73	21.12	1.68	11.53	25.34	1.76	13.71
T_4-MP	19.10	1.57	8.46	21.01	1.70	10.2	25.76	1.72	11.03
T_5-MM	22.28	1.68	8.93	23.81	1.72	10.53	25	1.72	11.7
T_6-MD	19.63	1.59	8.6	25.84	1.60	10.06	25.87	1.67	10.46
T_7-SP	22.21	1.58	8.8	22.54	1.62	10.66	23.65	1.63	10.73
T_8-SM	21.57	1.63	9.53	21.57	1.63	10.6	23.72	1.69	11.06
T_9-SD	18.96	1.57	9.33	19.96	1.61	9.3	21.84	1.64	10.53
F-Value	0.66^{NS}	0.93^{NS}	0.38^{NS}	0.64^{NS}	0.32^{NS}	0.93^{NS}	1.02^{NS}	0.32^{NS}	1.30^{NS}
CD(0.05)	7.87	0.16	1.90	7.06	0.20	2.8	5.03	0.19	3.41

NS Not significant.

The height of the seedlings varied between 17.33 cm (T_2) and 22.28 cm (T_5) on the 60th day after germination. The girth during the period varied from 1.55 cm (T_2) to 1.68 cm (T_5) while the number of leaves varied from 8.33 cm (T_9) to 8.73 (T_3). The maximum height recorded at 75th day after germination was 26.84 cm (T_6) and the minimum 20.34 cm (T_2). The girth for the same period ranged from 1.60 cm (T_6) to 1.72 cm (T_5) while the number of leaves produced varied from 9.3 (T_9) to 11.53 (T_3).

The maximum height observed was 25.97 cm (T_6) and the minimum 21.25 cm (T_1) on the 90th day. The girth during the period varied from 1.63 cm (T_7) to 1.76 cm (T_3) while the number of leaves varied from 9.6 (T_1) to 13.71(T_3).

Considering the effect of pod size alone (Table 6b) there was no significant difference in the height and number of leaves at any of the intervals while the girth was significantly higher for 'large' on the 15th day only.

Taking into account effect of the position of the seed (Table 6c) there was no significant difference in the height and girth of the seedlings at any of the intervals of recording while the number of leaves produced was significantly higher on the 45th day for Middle.

Table 6b. Shoot growth parameters of cocoa seedlings at various intervals sown in different months. January sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Large	13.87	1.41	3.91	16.14	1.52	5.08	17.16	1.59	7.33
Medium	15.30	1.35	3.91	18.13	1.54	4.71	18.73	1.59	7.11
Small	13.61	1.27	3.91	16.63	1.51	5.06	17.27	1.53	7.4
F-Value	3.44^{NS}	3.09*0.00027^{NS}		2.44^{NS}	0.41^{NS}	1.55^{NS}	2.61^{NS}	2.69^{NS}	0.93^{NS}
CD(0.05)	1.45	0.10	0.34	1.97	0.08	0.50	1.61	0.06	0.43

NS Not significant

* Significant at 5% level.

Table 6b. Continued

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Large	19.40	1.62	9.40	20.79	1.67	10.44	22.65	1.72	11.81
Medium	20.34	1.61	8.66	23.55	1.67	10.26	25.58	1.70	11.06
Small	20.91	1.59	8.08	21.36	1.62	10.18	23.07	1.65	10.77
F-Value	0.24^{NS}	0.12^{NS}	1.02^{NS}	1.12^{NS}	0.63^{NS}	0.05^{NS}	2.61^{NS}	0.87^{NS}	0.65^{NS}
CD(0.05)	4.54	0.10	1.10	4.03	0.11	1.61	2.90	0.10	1.97

NS Not significant.

Table 6c. Shoot growth parameters of cocoa seedlings various intervals sown in different months. January sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Pedicel end.	14.63	1.33	3.84	17.00	1.52	5.11	17.58	1.58	7.06
Middle	14.14	1.40	4.02	16.95	1.52	5.13	18.20	1.58	7.63
Distal end.	14.01	1.30	3.87	16.95	1.52	4.62	17.38	1.55	7.14
F-Value	0.45^{NS}	1.74^{NS}	0.67^{NS}	0.02^{NS}	0.00^{NS}	2.88^{NS}	0.61^{NS}	0.41^{NS}	4.06*
CD(0.05)	1.45	0.10	0.34	1.97	0.08	0.50	1.61	0.06	0.45

NS Not significant
* Significant at 5% level.

Table 6c Continued.

Days after germination	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Pedicel end.	20.36	1.60	8.68	21.49	1.67	10.08	23.59	1.60	10.48
Middle	20.39	1.62	9.37	21.90	1.67	10.51	23.36	1.70	11.63
Distal end.	19.90	1.60	8.69	22.30	1.63	10.30	24.38	1.69	11.57
F-Value	0.03^{NS}	0.07^{NS}	0.91^{NS}	0.09^{NS}	0.42^{NS}	0.15^{NS}	0.30^{NS}	0.04^{NS}	0.99^{NS}
CD(0.05)	4.54	0.10	1.10	4.33	0.11	1.61	2.90	0.10	1.97

NS Not significant

(ii) Root growth.

The data on the mean length of the tap root, length of longest lateral root and the number of lateral roots are given in Table 7a.

There was no significant difference in the length of the tap root and the length of the longest lateral root at any of the intervals while the number of lateral roots showed significant variation on the 90th day only.

The maximum length of the tap root on the 30th day after germination was 14.09 cm (T_5) and the minimum was 12.65 (T_9). The length of the longest lateral root for the period varied from 3.11 cm (T_6) to 4.73 cm (T_5) while the number of lateral roots ranged from 29.33 (T_1) to 39 (T_3).

On the 60th day after germination the maximum length of the tap root observed was 16.5 cm (T_5) and the minimum 13.55 cm (T_1 and T_2) while the longest lateral root varied in length from 3.93 cm (T_1) to 5.93 cm (T_5). The number of lateral roots for the period varied from 31.33 (T_1) to 44 (T_5).

The tap root varied in length from 14.08 cm (T_9) to 17.38 cm (T_5) on 90th day, while the longest lateral root varied in length from 4.16 cm to 8.24 cm. The number of lateral roots was significantly higher in T_4(54). T_4 was

Table 7a. Root growth parameters of cocoa seedlings at various intervals sown in different months. January sowing.

Days after germination	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No. of lateral roots.
T_1-LD	13.37	3.87	29.33	13.55	3.93	31.33	14.76	4.16	43.66
T_2-LM	12.78	4.43	30.33	13.55	4.56	38.66	15.41	8.24	48.33
T_3-LD	13.1	4.42	39	16.04	5.18	42	16.81	7.28	43.33
T_4-MD	13.19	4.10	34	14.11	4.24	39	15.40	4.92	54
T_5-MM	14.09	4.73	35.66	16.5	5.93	44	17.38	7.19	48
T_6-MD	12.95	3.11	33.66	14.51	4.36	38.33	14.82	4.45	47
T_7-SD	13.11	3.24	35.33	14.38	4.02	36	15.49	6.61	47.33
T_8-SM	13.96	4.52	34.33	14.78	4.6	36	14.82	5.81	50.33
T_9-SD	12.65	3.28	33.33	13.59	4.52	34.66	14.03	6.68	47.66
F-Value	0.28^{NS}	1.36^{NS}	1.97^{NS}	0.42^{NS}	0.46^{NS}	0.77^{NS}	0.76^{NS}	0.79^{NS}	3.06*
CD(0.05)	2.80	1.24	7.55	5.89	2.50	12.30	4.13	4.06	5.77

NS Not significant.
* Significant at 5% level.

on par with T_8, T_2, and T_3. The number observed was lowest for T_1(43.66).

Taking into account the size of the pod only (Table 7b) there was no significant difference in any of the root characters at any of the intervals of recording.

Considering the position of the seed alone (Table 7c) there was no significant difference in the length of the tap root and the number of the lateral roots at any of the intervals of recording. The length of the longest lateral root was significantly higher for 'middle' on the 30th day only.

(iii) Dry weight.

The mean dry weight of the shoot and the root and the total dry weight are presented in Table 8a.

There was no significant difference in the dry weight of the shoot and the root as well as the total dry weight at any of the intervals.

On the 30th day after germination the mean dry weight of the shoot varied from 750 mg (T_3) to 1056.22 (T_8) while that of the root varied from 194.66 mg (T_6) to 249 mg (T_1). The total dry weight for the same period ranged from 869.33mg (T_7) to 1290.39 mg (T_8).

The dry weight of the shoot was highest for T_5 (1556.66 mg) and lowest for T_9(1166.66 mg) while that of

Table 7b. Root growth parameters of cocoa seedlings at various intervals sown in different months. January sowing.

Days after germination	30th day			60th day			90th day		
Treatments.	Length of tap root.	Length of longest lateral root.	No.of lateral roots.	Length of tap root.	Length of longest lateral root.	No.of lateral roots.	Length of tap root.	Length of longest lateral root.	No.of lateral roots
	(cm)	(cm)		(cm)	(cm)		(cm)	(cm)	
Large	13.08	4.26	32.88	14.38	4.55	37.33	15.66	5.23	46.77
Medium	13.41	3.98	34.44	15.04	4.84	40.44	15.87	7.08	49.66
Small	13.24	3.60	34.38	14.25	4.32	38.55	14.80	6.12	48.44
F-Value	0.09^{NS}	3.43^{NS}	0.34^{NS}	0.13^{NS}	0.23^{NS}	1.07^{NS}	0.50^{NS}	0.92^{NS}	1.66^{NS}
CD(0.05)	1.61	0.71	4.35	3.46	1.44	7.10	3.33	2.86	9.33

NS Not significant.

Table 7c. Root growth parameters of cocoa seedlings at various intervals sown in different months. January sowing.

Days after germination	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of laterals roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of laterals roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of laterals roots.
Pedicel end.	13.22	3.74	32.88	14.01	4.06	35.44	15.22	6.56	40.33
Middle	13.61	4.58	33.44	14.94	5.03	39.55	15.87	5.50	48.89
Distal end.	12.90	3.60	35.33	14.71	4.69	38.33	15.24	6.37	47.66
F.Value	0.42^{NS}	4.79*	0.76^{NS}	0.17	^{NS}1.01^{NS}	0.77^{NS}	0.21^{NS}	0.36^{NS}	0.29^{NS}
CD(0.05)	1.61	0.71	4.35	3.40	1.44	7.10	2.38	2.96	3.33

NS Not significant.

Table 8a. Dry weight of coca seedlings at various intervals sown in different months. January sowing.

Days after germination.	30th day			60th day			90th day		
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
T_1-LP	908.82	249	1157.82	1353.33	266.33	1619.66	1597.5	317.33	1914.83
T_2-LM	980.67	196.66	1177.33	1250	241.66	1491.66	1803.33	437.33	2240.66
T_3-LD	750	210.66	960.66	1417.5	266.83	1684.33	1636.66	436.66	2073.33
T_4-MP	877.33	224.83	1102.16	1366.66	293	1664.66	1096.66	438.33	2335.00
T_5-MM	945	236.66	1181.66	1556.66	334.66	1891.32	1802	548	2350.00
T_6-MD	870	194.66	1064.66	1503.33	307	1910.33	1541.66	317.66	1859.33
T_7-SP	661.67	207.66	869.33	1412.5	224.16	1636.66	1766.66	417.33	2184.00
T_8-SM	1056.22	234.66	1290.89	1494	244.66	1738.66	1758.89	356.66	2115.55
T_9-SD	853.66	221	1074.66	1166.66	241.33	1408	2100	367.33	2467.33
F-Value	2.42^{NS}	0.435^{NS}	1.72^{NS}	0.604^{NS}	0.32^{NS}	0.65^{NS}	0.828^{NS}	0.76^{NS}	0.81^{NS}
CD(0.05)	210.56	106.1	279.16	518.03	89.47	558.93	663.37	290.50	841.07

NS Not significant

the root was highest for T_5(334.66 mg) and lowest for T_7 (224.16 mg) on the 60th day. The total dry weight for the same period varied between 1408 mg for T_9) and 1891.32 mg for T_5.

On the 90th day after germination the maximum dry weight of the shoot was obtained for T_9 (2100 mg) and the minimum for T_6(1541.66 mg) while corresponding figures for the root was obtained for T_5 (543 mg) and T_1(317.33 mg). The total dry weight for the same period varied from 1359.33 mg for T_6 and 2467.33 mg for T_9.

Taking into account of the effect of pod size alone (Table 8b) there was no significant difference in the dry weight of the shoot and the total dry weight at any of the intervals of recording. The dry weight of the root was significantly higher for 'medium'.

Considering the effect of seed position by itself (Table 8c) the dry weight of the shoot varied significantly on the 30th day only when the weight was significantly higher for 'middle' while there was no significant difference at any of the intervals of recording. The total dry weight was significantly higher for 'middle' on the 30th day alone.

Table 8b. Dry weight of cocoa seedlings at various intervals sown in different months. January sowing.

Days after germination	30th day			60th day			90th day		
Treatments.	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
Large	879.83	218.77	1098.60	1340.27	258.27	1598.55	1679.16	397.11	2076.27
Medium	897.44	218.72	1116.16	1475.55	313.22	1788.77	1746.77	434.66	2181.44
Small	857.18	221.11	1078.29	1357.72	236.72	1594.55	1875.18	380.44	2255.63
F-Value	0.24^{NS}	0.0043^{NS}	0.12^{NS}	0.53^{NS}	5.14 *	1.04^{NS}	0.59^{NS}	0.81^{NS}	0.30^{NS}
CD(0.05)	121.55	61.25	161.17	299.08	51.66	322.70	382.99	167.72	485.59

NS Not significant
* Significant at 5% level.

Table 8c. Dry weight of cocoa seedlings at various intervals sown in different months.
January sowing.

Days after germination									
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
Pedicel end	815.94	227.16	1043.10	1377.5	262.83	1640.33	1753.61	391.00	2144.61
Middle	993.96	222.66	1216.63	1433.55	273.66	1707.22	1738.07	447.33	2235.40
Distal end	824.55	208.77	1033.33	1362.5	271.92	1634.33	1759.44	373.88	2133.33
F-Value	6.02**	0.21^{NS}	3.61*	0.13^{NS}	0.11^{NS}	0.13^{NS}	0.02^{NS}	0.46^{NS}	0.11^{NS}
CD(0.05)	121.55	61.25	161.17	299.03	51.66	322.70	382.99	167.72	486.59

NS Not significant.
* Significant at 5% level.
** Significant at 1% level.

1.4.3 February sowing.

(1) Vegetative growth.

The data on the height, girth and number of leaves of the seedlings are presented in Table 9a and Figure 1.

There was no significant difference in the height as well as the number of leaves at any of the intervals of recording while there was significant difference on the girth on the 90th day only. The height of the seedling ranged from 15.23 cm (T_7) to 17.41 cm (T_1) while the girth ranged from 1.33 cm (T_9) to 1.49 cm (T_8). The number of leaves produced during the period varied from 3.67(T_8) to 4.07 (T_2).

On the 30th day after germination the maximum height observed was 21.54 cm (T_5) and the minimum height observed 17.7 cm (T_9). The girth varied from 1.34 cm (T_9) to 1.55 cm (T_3) while the number of leaves varied from 5.47 (T_9) to 7 (T_5). The height of the seedling ranged from 19.5 cm (T_7) to 23.48 cm (T_6) on the 45th day after germination while the girth for the same period ranged from 1.40 cm (T_9) to 1.56 cm (T_2). The number of leaves produced was highest for 76 (7.87) and lowest for T_1(6.53).

Onthe 60th day the maximum height observed was 26.48 cm (T_2) and the minimum 21.45 cm (T_1) while the girth ranged from 1.52 cm (T_1 and T_4) to 1.66 cm (T_3). The maximum number of leaves produced was 10.46 (T_5) and the

Table 9a. Shoot growth parameters of cocoa seedlings at various intervals in different months. February sowing.

Days after germination	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1-LP	17.41	1.43	3.93	20.12	1.44	5.87	21.24	1.47	6.53
T_2-LM	17.23	1.39	4.07	20.68	1.51	6.53	21.98	1.56	7.53
T_3-LD	17.14	1.38	3.8	20.80	1.55	5.87	21.42	1.54	7.8
T_4-MP	16.93	1.37	3.93	20.58	1.49	6.53	21.86	1.51	7.53
T_5-MM	17.33	1.38	3.87	21.54	1.49	7	22.28	1.54	7.2
T_6-MD	17.23	1.39	3.8	19.62	1.5	6.27	23.48	1.5	7.87
T_7-SP	15.23	1.35	3.8	19.32	1.42	5.83	19.5	1.46	7.13
T_8-SM	16.53	1.49	3.67	18.96	1.42	6.13	20.6	1.54	6.6
T_9-SD	16.07	1.33	3.73	17.7	1.34	5.47	19.6	1.40	6.67
F-Value	0.15^{NS}	0.60^{NS}	0.15^{NS}	0.17^{NS}	1.49^{NS}	0.27^{NS}	0.20^{NS}	0.46^{NS}	1.24^{NS}
CD(0.05)	2.94	0.21	0.71	5.02	0.12	0.62	4.03	0.17	1.35

NS Not significant.

Table 9a. Continued

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1-LP	21.45	1.52	7.96	26.34	1.64	10.06	36.9	2.12	12.67
T_2-LM	26.48	1.61	10.4	27.91	1.61	11.8	3 1.39	1.78	11.8
T_3-LD	22.36	1.66	8.93	24.57	1.71	10.53	33.27	2.04	12.23
T_4-MP	23.07	1.52	8.3	23.26	1.64	10.9	36.19	1.95	12.93
T_5-MM	22.56	1.60	10.46	29.55	1.8	11.8	29.37	1.97	12.87
T_6-MD	23.74	1.60	8.9	24.69	1.64	10.4	35.60	2.14	13.8
T_7-SP	22.09	1.62	8.56	24.20	1.63	10.33	31.71	2.04	12.33
T_8-SM	24.41	1.60	9.03	25.04	1.64	9.8	33.24	1.96	11.13
T_9-SD	23.08	1.55	9.16	26.26	1.61	10.26	28.25	1.98	11.73
F-Value	0.83^{NS}	0.69^{NS}	0.94^{NS}	0.79^{NS}	0.67^{NS}	0.02^{NS}	0.42^{NS}	2.95*	0.35^{NS}
CD(0.05)	4.67	0.19	2.36	6.54	0.24	2.15	13.94	0.18	2.1

NS. Not significant.
* Significant at 5%level.

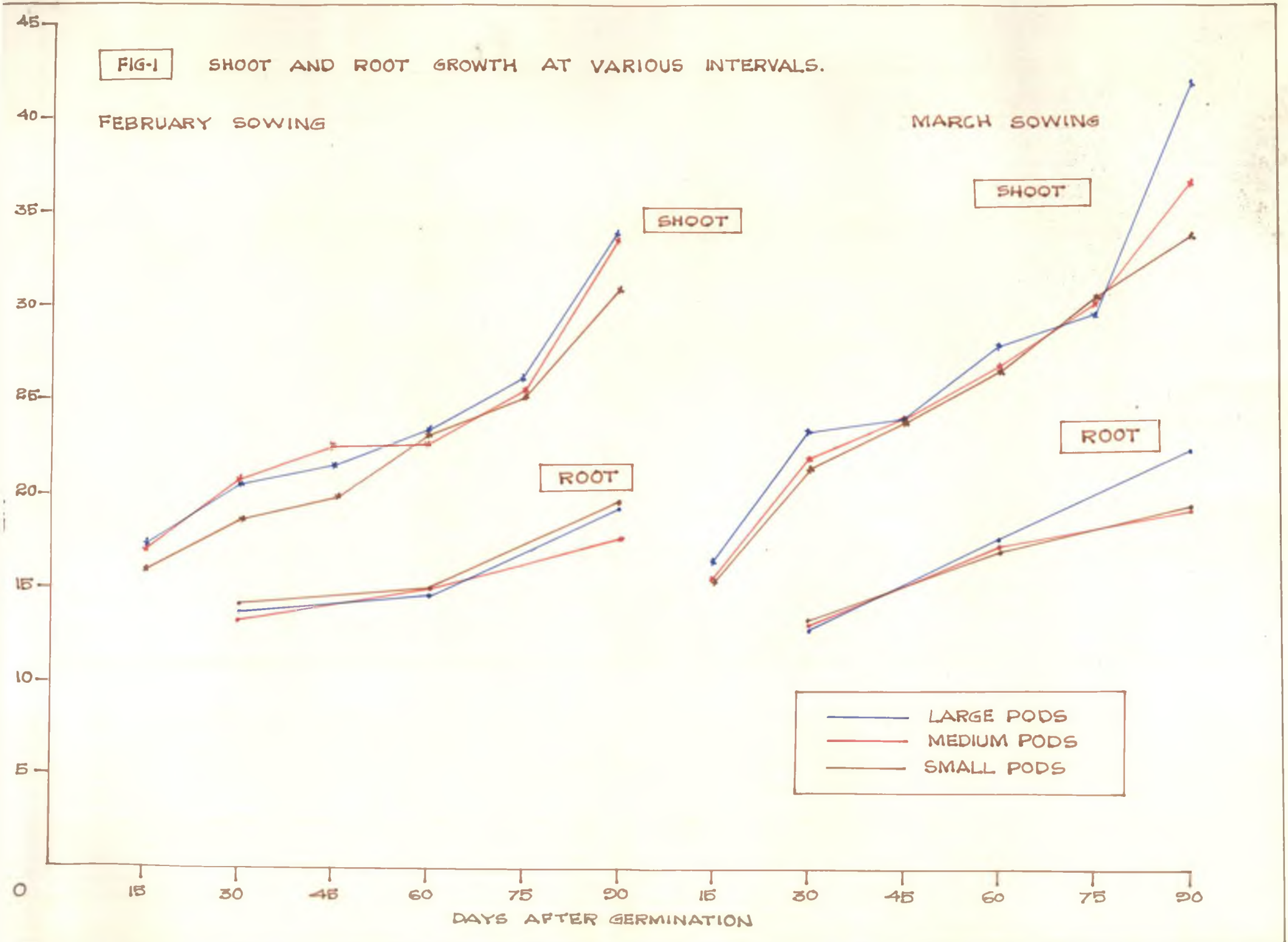


FIG-1 SHOOT AND ROOT GROWTH AT VARIOUS INTERVALS.
FEBRUARY SOWING
MARCH SOWING
SHOOT
ROOT
SHOOT
ROOT
LARGE PODS
MEDIUM PODS
SMALL PODS
45
40
35
30
25
20
15
10
5
0
15
30
45
60
75
90
15
30
45
60
75
90
DAYS AFTER GERMINATION

minimum 7.96 (T_1).

The height ranged from 23.26 cm (T_4) to 29.55 cm(T_5) on the 75th day. The maximum girth observed for the period was 1.71 cm (T_3) and the minimum 1.61 cm (T_2 and T_9). The number of leaves produced varied from 9.8 (T_8) to 11.8 (T_5).

The height of the seedling ranged from 28.25 cm (T_9) to 36.9 cm (T_1) on the 90th day after germination. The girth was significantly higher in T_6(2.14 cm). T_6 was on par with T_1, T_3, T_7, T_9, T_5 and T_8. The minimum girth was observed for T_2(1.78 cm).

Considering the main effect of pod size by itself (Table 9b) there was no significant difference in the height of the seedlings at any of the intervals while the girth and number of leaves produced showed significant variation only on the 30th day after germination. The girth was significantly higher for 'large' while the number of leaves produced was significant for 'medium' during this period.

Based on the position of the seed alone (Table 9c) there was no significant difference in the height at any of the intervals of recording while the girth was significantly higher on the 90th day only for'distal end'. The number of leaves produced was significantly higher for 'middle' only on the 30th day.

Table 9b. Shoot growth parameters of cocoa seedlings at various intervals in different months. February sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves
Large	17.25	1.4	3.93	20.53	1.5	6.08	21.55	1.52	7.28
Medium	17.16	1.38	3.86	20.58	1.49	6.6	22.54	1.51	7.93
Small	15.94	1.38	3.73	18.66	1.39	5.81	19.90	1.46	6.8
F-Value	1.64^{NS}	0.049^{NS}	0.55^{NS}	1.25^{NS}	6.61^{**}	11.02^{**}	2.89^{NS}	0.88^{NS}	2.01^{NS}
CD(0.05)	1.69	0.11	0.4	2.89	0.06	0.35	2.32	0.09	0.78

NS Not significant
** Significant at 1% level.

Table 9b. Continued

Days after germination	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Large	23.43	1.60	9.10	26.27	1.65	10.8	33.85	1.98	12.23
Medium	23.79	1.57	9.22	25.93	1.69	11.00	33.74	2.02	13.2
Small	23.19	1.59	8.92	25.20	1.63	10.13	31.06	1.99	11.73
F-Value	0.12^{NS}	0.13^{NS}	0.10^{NS}	0.18^{NS}	0.44^{NS}	1.17^{NS}	0.33^{NS}	0.33^{NS}	3.33^{NS}
CD(0.05)	2.69	0.11	1.36	3.77	0.14	1.24	8.04	0.10	1.21

NS Not significant.

Table 9c. Shoot growth parameters of cocoa seedlings at various intervals sown in different months. February sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Pedicel end	16.52	1.38	3.88	20.00	1.45	6.07	20.87	1.48	7.06
Middle	17.03	1.42	3.86	20.39	1.47	6.55	21.62	1.54	7.11
Distal end	16.81	1.36	3.77	19.37	1.46	5.86	21.50	1.48	7.44
F-Value	1.97^{NS}	0.43^{NS}	0.18^{NS}	0.27^{NS}	0.18^{NS}	8.57**	0.28^{NS}	1.29^{NS}	0.61^{NS}
CD(0.05)	1.69	0.11	0.4	2.89	0.06	0.35	2.32	0.09	0.78

NS Not significant.
** Significant at 1% level.

Table 9c. Continued

Days after germination	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Pedicel end.	21.67	1.55	8.27	24.62	1.64	10.4	34.93	2.03	12.64
Middle	24.48	1.60	9.96	27.50	1.68	11.13	31.33	1.91	11.93
Distal end.	23.06	1.60	9.00	25.17	1.65	10.4	32.4	2.06	12.58
F-Value	2.06^{NS}	0.65^{NS}	3.39^{NS}	1.44^{NS}	0.23^{NS}	1.01^{NS}	0.46^{NS}	4.93*	0.93^{NS}
CD(0.05)	2.69	0.11	1.26	3.77	0.14	1.24	8.04	0.10	1.21

NS Not significant
* Significant at 5% level.

(ii) Root growth.

The data on the length of the tap root, the length of the longest lateral root and the number of lateral roots are presented in Table 10a and figure 1. The graphical representation for the root growth for February and March is presented in figure 1.

There was no significant difference at any of the intervals of recording for any of the root characters. On the 30th day after germination the length of the tap root varied from 12.58 cm (T_4) to 14.7 cm (T_8) while the length of the longest lateral root varied from 3.03 cm(T_8) to 5.24 cm (T_2). The mean number of lateral roots varied from 30.66 (T_7) to 42.33 (T_2).

On the 60th day the maximum length of tap root was observed for T_5(16.36 cm) and the minimum for T_4(13.9 cm) while the longest lateral root varied from 3.64 cm to 5.65 cm (T_2). The number of lateral root produced was highest for T_3(57) and lowest for T_8(38).

The maximum length of the tap root produced on the 90th day after germination was 20.59 cm (T_1) and the minimum 16.43 cm (T_5). The length of the longest lateral root varied from 5 cm (T_7) to 10.14 cm (T_1). The number of lateral roots produced was highest for T_5 (64.86) and lowest for T_9 (48.66).

Table 10a. Root growth parameters of cocoa seedlings at various intervals sown in different months. February sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.
T_1-LP	12.75	3.46	31.66	14.32	4.74	46.33	20.59	10.14	55.33
T_2-LM	14.46	5.24	42.33	14.65	5.65	47.33	17.95	7.94	54.66
T_3-LD	13.94	4.44	34	15.18	4.47	57	19.45	7.60	64.33
T_4-MP	12.58	3.64	33	13.9	4.14	51.66	18.73	8.05	51.66
T_5-MM	14.43	5.06	36.33	16.36	5.21	45.33	16.43	6.41	64.86
T_6-MD	13.74	4.22	35.66	14.07	4.67	40.33	18.35	8.32	55.33
T_7-SP	13.56	3.38	30.66	15.20	3.64	39.66	17.14	5	46.33
T_8-SM	14.7	3.03	36.66	15.42	4.15	38	20.37	8.08	51
T_9-SD	13.91	3.40	38	14.04	3.94	38.33	20.29	5.57	48.66
F-Value	0.04^{NS}	1.18^{NS}	1.19^{NS}	0.21^{NS}	0.23^{NS}	1.77^{NS}	1.05^{NS}	1.91^{NS}	0.79^{NS}
CD(0.05)	3.64	1.60	7.55	5.62	1.78	12.54	4.92	3.77	16.92

NS Not significant.

Regarding the effect of pod size alone (Table 10b) there was no significant difference in the length of the tap root at any of the intervals of recording while the length of longest lateral root was significantly higher for 'large' only on the 30th day after germination.

The number of lateral roots produced showed significant variation only on the 60th day when the number was significantly higher for 'large'. On the 90th day there was no significant difference for any of the root characters.

Considering the main effect of seed position only (Table 10c) there was no significant difference in the length of the tap root or that of the longest lateral root at any of the intervals of recording while the number of lateral roots produced showed significant difference only on the 30th day when the number was significantly higher for middle.

(iii) Dry weight.

The mean dry weight of the shoot and the root and the total dry weight are presented in Table 11a and figure 2.

There was no significant difference in the dry weights of the shoot and the root and the total dry weight at any of the intervals. On the 30th day the dry weight of the shoot varied from 741.66 mg (T_9) to 1213.33 mg (T_5) while that of the root varied from 177.33 mg (79) to 229.33 mg(T_5).

Table 10b. Root growth parameters of cocoa seedlings at various intervals sown in different months. February sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.
Large	13.71	4.38	36.00	14.71	4.95	50.22	19.33	8.56	50.11
Medium	13.58	4.31	35.00	14.77	4.67	45.77	17.83	8.02	57.20
Small	14.06	3.27	35.11	14.89	3.91	38.66	19.26	6.2	48.66
F-Value	0.11^{NS}	4.3*	0.13^{NS}	0.10^{NS}	2.42^{NS}	5.71*	0.78^{NS}	2.84^{NS}	2.53^{NS}
CD(0.05)	3.10	0.9	4.41	3.24	1.03	7.24	2.93	3.17	9.76

NS Not significant
* Significant at 5% level.

Table 10c. Root growth parameters of cocoa seedlings at various intervals sown indifferent months. February sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root.	Length of longest lateral root.	No.of lateral roots.	Length of tap root.	Length of longest lateral root.	No.of lateral roots.	Length of tap root.	Length of longest lateral root.	No. of lateral roots.
	(cm)	(cm)		(cm)	(cm)		(cm)	(cm)	
Pedicel end.	12.96	3.49	31.77	14.47	4.18	45.88	18.82	7.99	51.11
Middle	14.53	4.44	38.44	15.48	5.00	43.55	18.25	7.46	56.84
Distal end.	13.86	4.02	35.88	14.43	4.36	45.22	19.36	7.33	56.11
F-Value	1.22^{NS}	2.3^{NS}	5.11*	0.29 ^{NS}	1.55^{NS}	0.24^{NS}	0.33^{NS}	0.23^{NS}	0.90^{NS}
CD(0.05)	3.10	0.9	4.41	3.24	1.03	7.24	2.88	2.17	9.76

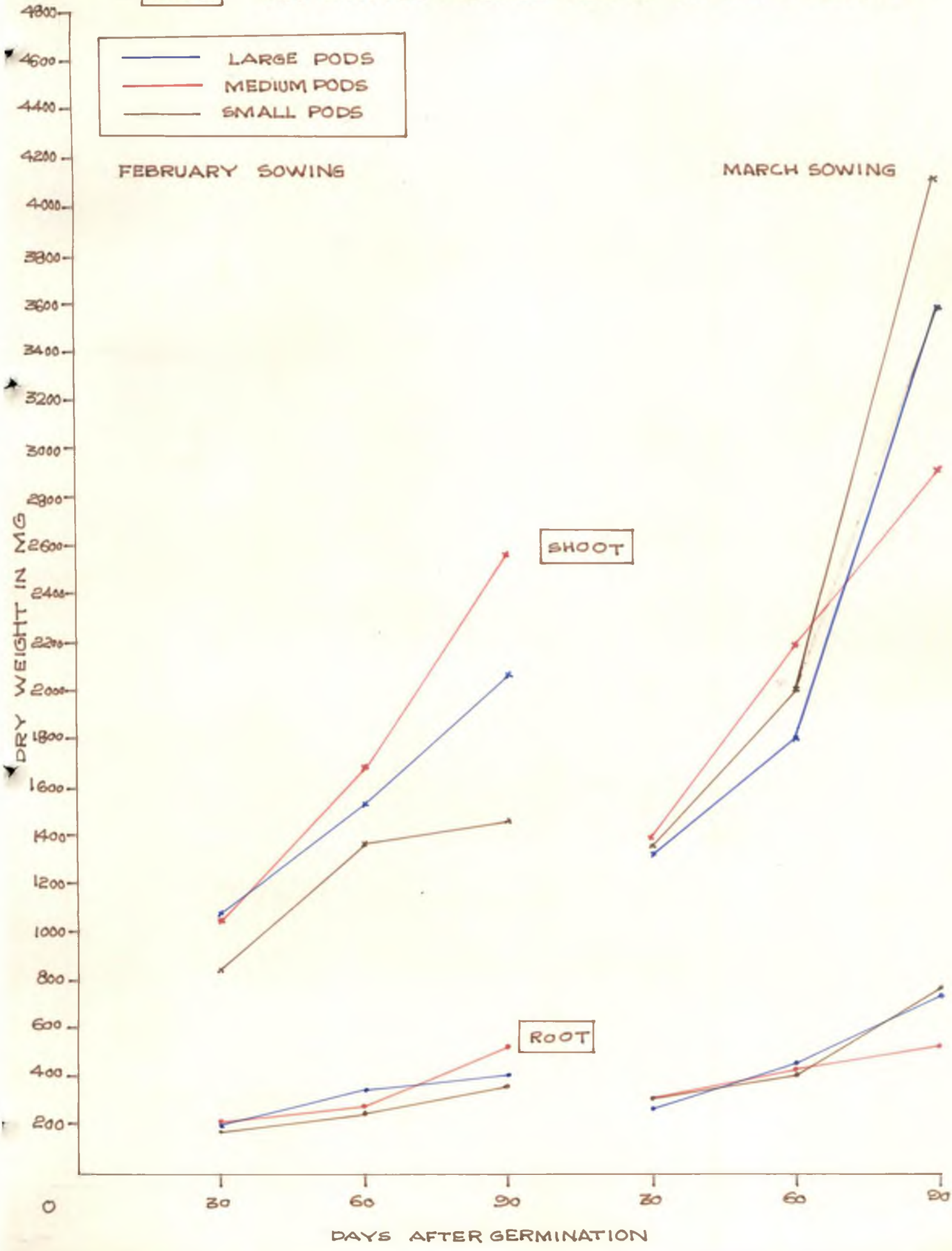
NS Not significant
* Significant at 5% level.

Table 11a. Dry weight of cocoa seedlings at various intervals sown in different months. February sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
T_1-LP	933.33	193.33	1131.66	1537	343.33	1880.33	2303.73	441.73	2745.46
T_2-LM	1158.75	211.66	1370.41	1679.33	314.66	1994	1967.33	359.33	2326.66
T_3-LD	1202	206.33	1408.33	1423.33	401.66	1825	1928.66	409	2337.66
T_4-MP	943.33	189.66	1133.00	1444	258	1702	1859.33	424	2323.33
T_5-MM	1213.33	229.33	1442.66	1833.33	284	2122.33	3102.33	603.33	3705.66
T_6-MD	1030	194.33	1224.33	1777.5	301.46	2708.96	2648.66	572.66	3221.33
T_7-SP	874.66	201	1075.66	1325	258.33	1583.33	1494.66	369.33	1864.00
T_8-SM	920	197.66	1117.66	1404.33	278.66	1683	1444.66	366.66	1811.33
T_9-SD	741.66	177.33	919.00	1383.33	263.66	1647.	1449.33	390	1849.33
F-Value	1.78^{NS}	1.5^{NS}	1.97^{NS}	0.91^{NS}	1.64^{NS}	0.74^{NS}	1.21^{NS}	1.02^{NS}	1.24^{NS}
CD(0.05)	240.74	32.009	254.13	339.55	78.57	417.73	1137.93	202.09	1303.93

NS Not significant

FIG-2 DRY MATTER ACCUMULATION AT VARIOUS INTERVALS



The total dry weight varied from 919 mg (T_9) to 1442.66 mg (T_5).

The dry weight of the shoot ranged from 1325 mg (T_7) to 1838.33 mg (T_5) while that of the root ranged from 258 mg (T_4) to 401.66 mg (T_3) on 60th day. The total dry weight for the same period varied from 1583.33 mg (T_7) to 2122.33 mg (T_5).

At the 90th day after germination the maximum dry weight of the shoot obtained was 3102.33 mg (T_5) and the minimum 1444.66 mg (T_8). The dry weight of the root varied from 359.33 mg (T_2) to 603.33 mg (T_5). The total dry weight for the period ranged from 1811.33 mg (T_9) to 3705.66mg(T_5).

With respect to the effect of the pod size(Table 11b) the dry weight of the shoot was significantly higher for 'large' on the 30th day and for 'medium' on the 60th and 90th day while that of the root was significantly higher for 'large' on the 60th day and for 'medium' on the 90th day.

The total dry weight was significantly higher for 'large' on 30th day and for 'medium' on the 60th and 90th days.

With regard to the effect of seed position (Table 11c) the dry weight of the shoot and the total dry weight were significannly higher for 'middle' on the 30th day only while there was no significant difference on the dry weight of the root at any of the intervals of recording.

Table 11b. Dry weight of cocoa seedlings at various intervals sown in different months. February sowing.

Days after germination									
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
Large	1099.69	203.77	1303.47	1546.55	353.22	1899.77	2066.57	403.35	2469.93
Medium	1062.22	204.44	1266.66	1686.61	281.15	1967.76	2580.11	533.33	3093.44
Small	845.44	192.00	1037.44	1370.83	266.88	1637.72	1462.88	372.00	1841.55
F-Value	3.5**	1.26^{NS}	3.52**	4.36*	9.18**	4.6*	6.06**	4.74*	5.00*
CD(0.05)	128.93	13.52	146.72	224.91	45.36	241.17	656.93	116.67	752.02

NS Not significant
* Significant at 5% level
** Significant at 1% level.

Table 11c. Dry weight of cocoa seedlings at various intervals sown in different months. February sowing.

Days after germination	30 days			60 days			90 days		
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
Rediselend	918.77	194.66	1113.44	1435.33	286.55	1721.88	1899.24	411.68	2310.93
Middle	1097.36	212.88	1310.25	1640.66	292.44	1933.11	2171.44	443.11	2614.55
Distal end	991.22	192.66	1183.88	1529.05	322.26	1850.32	2008.98	459.83	2469.44
F-Value	3.68*	3.19^{NS}	4.07*	1.84^{NS}	1.57^{NS}	1.71^{NS}	0.39^{NS}	0.31^{NS}	0.35^{NS}
CD(0.05)	138.93	18.52	146.72	224.91	45.36	241.17	656.98	116.67	752.62

NS Not significant
* Significant at 5% level.

1.4.4 March sowing.

(i) Vegetative growth.

The data on the height, girth and number of leaves of the seedlings are presented in Table 12a and Figure 1.

There was no significant difference in the height, girth and number of leaves at any of the intervals of recording. The height of the seedling on the 15th day after germination varied from 14.69 cm (T_5) to 16.91 cm(T_2). The girth for the same period varied from 1.4 cm (T_4) to 1.48 cm (T_1 and T_2). The maximum number of leaves were produced in T_5(3.47) and the minimum in T_3 (2.93). On the 30th day the maximum height of the seedlings was recorded for T_2 (23.76 cm) and the minimum for T_8 (20.97 cm) while the girth varied from 1.46 cm (T_4 and T_6) to 1.52 cm (T_3 and T_9). The number of leaves produced varied from 5.93 (T_6) to 7.6 (T_5). The maximum height recorded was 25.39 cm (T_4) and the minimum 23.3 cm (T_7) on 45th day. The girth for the same period varied from 1.53 cm (T_5) to 1.77 cm (T_9) while the number of leaves produced were highest in T_9(10.06) and lowest in T_6 (8.83).

On the 60th day the height of the seedlings varied from 24.81 cm (T_9) to 29 cm (T_1) while the girth varied from 1.64 cm (T_3) to 1.85 cm (T_8). The number of leaves for the same period ranged from 9.93 (T_4) to 10.93 (T_2).

Table 12a. Shoot growth parameters of cocoa seedlings at various intervals sown in different months. March sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1-LP	16.55	1.48	3.03	23.3	1.50	6.67	23.31	1.62	9.13
T_2-LM	16.91	1.48	3.2	23.76	1.49	7.53	24.88	1.64	9.46
T_3-LD	16.07	1.45	2.93	23.56	1.52	7.27	24.74	1.54	9.66
T_4-MP	15.78	1.4	3.13	21.18	1.46	6.47	25.39	1.62	9.86
T_5-MM	16.37	1.46	3.47	23.10	1.50	7.6	24.22	1.53	10.00
T_6-MD	14.69	1.42	3.2	21.66	1.46	5.93	23.35	1.57	8.83
T_7-SP	16.72	1.44	3.4	21.19	1.50	6.87	23.30	1.56	9.66
T_8-SM	14.76	1.44	3.33	20.97	1.50	7.2	23.93	1.63	9.60
T_9-SD	15.16	1.42	3.17	22.13	1.52	7.13	24.32	1.77	10.06
F-Value	0.89^{NS}	0.55^{NS}	0.14^{NS}	0.53^{NS}	0.26^{NS}	1.42^{NS}	0.41^{NS}	2.09^{NS}	0.63^{NS}
CD(0.05)	2.36	0.07	0.83	2.87	0.12	1.15	4.60	0.18	1.90

NS Not significant.

Table 12a. Continued.

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1-LP	29	1.84	10.2	31.51	1.94	11.06	41.55	2.19	14.4
T_2-LM	27.00	1.74	10.93	29.51	2.02	11.13	43.6	2.62	13.53
T_3-LD	27.66	1.64	10.53	28.59	1.97	10.73	40.95	2.09	12.8
T_4-MP	28.34	1.67	9.93	30.07	1.81	11.33	37.73	2.25	13.09
T_5-MM	26.74	1.69	10.26	33.03	1.83	11.13	36.06	2.15	13.2
T_6-MD	27.93	1.76	10.53	28.35	1.83	10.73	36.91	2.15	12.8
T_7-SP	26.65	1.71	10.53	31.04	1.90	11.6	33.07	2.12	12.6
T_8-SM	28.75	1.85	10.53	31.51	1.88	11.53	37.31	2.13	15.19
T_9-SD	24.81	1.81	10.53	29.35	1.83	10.86	31.78	2.09	12.27
F-Value	0.76^{NS}	1.04^{NS}	0.12^{NS}	0.36^{NS}	0.41^{NS}	0.01^{NS}	0.42^{NS}	1.46^{NS}	0.69^{NS}
CD(0.05)	5.05	0.26	1.95	6.53	0.15	2.65	8.2	0.41	3.45

NS Not significant.

The maximum height recorded on the 75th day after germination was 33.03 cm (T_5) and the minimum 29.35 cm(T_6). The girth for the same period ranged from 1.81 cm (T_4) to 2.02 cm (T_2) while the number of leaves produced varied from 10.73 (T_3 and T_6) to 11.6 (T_7). On the 90th day after germination the maximum height recorded was 41.55 cm (T_1) and the minimum 31.78 cm (T_9) while the girth varied from 2.09 cm (T_3 and T_9) to 2.62 cm (T_2). The number of leaves produced for the same period ranged from 12.27 cm (T_9) to 15.19 cm (T_8).

Considering the effect of pod size by itself (Table 12b) the height was significantly higher for 'large' on the 15th, 30th and 90th days after germination. The girth was significantly higher for 'large' on the 75th day only while there was no significant difference in the number of leaves produced at any of the intervals of recording.

Regarding the effect of seed position alone (Table 12c) there was no significant difference in the height and girth of the seedlings at any of the intervals of recording while the number of leaves produced was significantly higher for 'middle' on the 30th day only.

(ii) Root growth.

The data on the mean length of the tap root, the length of the longest tap root and the number of lateral roots are presented in Table 13a and Figure 1.

Table 12b. Shoot growth parameters of cocoa seedlings at various intervals sown in different months. March sowing.

Days after germination	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Large	16.5	1.47	3.05	23.54	1.50	7.15	24.31	1.6	9.42
Medium	15.61	1.42	3.26	21.93	1.47	6.66	24.32	1.57	9.56
Small	15.54	1.43	3.3	21.43	1.51	7.06	23.85	1.65	9.77
F-Value	1.36^{NS}	2.67^{NS}	0.67^{NS}	3.83*	0.51^{NS}	1.36^{NS}	0.03^{NS}	1.44^{NS}	0.29^{NS}
CD(0.05)	1.36	0.04	0.48	1.65	0.07	0.66	2.65	0.106	1.09

NS Not significant

* Significant at 5% level.

Table 12b. Continued.

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Large	28.15	1.74	10.55	29.06	1.98	10.97	42.03	2.30	13.57
Medium	27.00	1.71	10.24	30.43	1.02	11.06	36.90	2.18	13.03
Small	26.74	1.79	10.53	30.63	1.07	11.33	34.05	2.11	13.35
F-Value	0.58^{NS}	0.63^{NS}	0.20^{NS}	0.102^{NS}	7.05**	0.13^{NS}	6.44**	1.47^{NS}	0.16^{NS}
CD(0.05)	2.91	0.15	1.13	3.77	0.08	1.53	4.73	0.23	1.99

NS Not significant
** Significant at 1% level.

Table 12c. Shoot growth parameters of coca seedlings at various intervals sown in different months. March sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves	Height (cm)	Girth (cm)	No.of leaves	Height (cm)	Girth (cm)	No.of leaves.
Pedicel end.	16.34	1.44	3.18	21.09	1.49	6.66	24.00	1.6	9.55
Middle	16.01	1.46	3.33	22.61	1.50	7.44	24.34	1.6	9.69
Distal end	15.3	1.43	3.1	22.45	1.50	6.77	24.14	1.62	9.52
F-Value	1.35^{NS}	0.95^{NS}	0.52^{NS}	0.45^{NS}	0.07^{NS}	3.57*	0.03^{NS}	0.18^{NS}	0.05^{NS}
CD(0.05)	1.36	0.04	0.48	1.65	0.07	0.66	2.65	0.106	1.09

NS Not significant
* Significant at 5% level.

Table 12c. Continued.

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves
Pedicel end.	27.33	1.74	10.22	30.87	1.88	11.33	37.45	2.10	13.36
Middle	27.76	1.76	10.57	31.34	1.91	11.26	38.99	2.3	13.97
Distal end	26.30	1.74	10.53	28.76	1.80	10.77	36.54	2.10	13.62
F-Value	0.24 NS	0.04 NS	0.25 NS	1.17 NS	0.42 NS	0.34 NS	0.6 NS	1.48 NS	1.02
CD(0.05)	3.91	0.15	1.13	3.77	0.09	1.53	4.79	0.33	1.99

NS Not significant

Table 13a. Root growth parameters of cocoa seedlings at various intervals sown in different months. March sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.
T_1-LP	12.77	3.73	31.33	16.81	5.95	37.66	21.77	12.13	57.33
T_2-LM	13.91	4.99	34.4	18.71	6.33	40.66	23.23	13.2	56.33
T_3-LD	11.33	3.57	36	17.78	6.45	41.33	22.49	9.62	50.33
T_4-MP	11.61	3.33	29.33	20.57	7.08	41.33	21.98	10.98	56.33
T_5-MM	13.94	3.92	31.33	15.77	7.09	44.66	18.29	8.59	54.33
T_6-MD	13.29	3.24	34.33	15.53	8.04	41.00	17.46	8.17	50.33
T_7-SP	12.11	3.5	32	17.67	4.92	39.66	10.35	11.07	47.67
T_8-SM	13.33	3.3	34	18.52	8.18	39.66	19.1	10.75	50.67
T_9-SD	14.07	3.66	32.33	15.56	7.16	33.66	20.35	10.55	54.67
F-Value	1.11^{NS}	2.18^{NS}	0.30^{NS}	1.69^{NS}	0.24^{NS}	3.32*	0.90^{NS}	0.18^{NS}	1.72^{NS}
CD(0.05)	3.01	0.96	7.95	4.57	4.75	4.11	5.6	7.76	9.06

NS Not significant
* Significant at 5% level.

There was no significant difference in the length of the tap root and that of the longest lateral root while for the number of lateral roots there was significant difference only on the 60th day after germination. On the 30th day after germination the length of the tap root was maximum in T_9 (14.07 cm) and minimum in T_4(11.61 cm) while the longest lateral root varied in length from 3.24cm (T_6) to 4.99 cm (T_2). The maximum number of lateral roots was produced in T_3(36) and the minimum in T_4 (29.33).

The length of the tap root varied from 15.53 cm (T_6) to 20.57 cm (T_4) and the length of the longest lateral root from 4.92 cm (T_7) to 8.18 cm (T_8) on 60th day. The number of lateral root produced was significantly higher for T_5(44.66). T_5 was on par with T_3, T_4, T_6 and T_2. The lowest number of lateral roots produced was for T_9(33.66). The length of the tap root varied from 17.46 cm (T_6) and 23.23 cm (T_2) on the 90th day after germination while that of the longest lateral root varied from 9.17 cm (T_6) to 13.2 cm (T_2). The number of lateral roots produced ranged from 47.67 (T_7) to 57.33 (T_1).

Considering the effect of pod size alone (Table 13b) the length of the tap root and that of the longest lateral root did not vary significantly at any of the intervals of recording while the number of lateral roots was significantly higher for 'medium' only on the 60th day.

Taking into account of the main effect of seed position alone (Table 13c) there was no significant variation

Table 13b. Root growth parameters of cocoa seedlings at various intervals sown in different months. March sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root.	Length of longest lateral root.	No.of lateral roots.	Length of tap root.	Length of longest lateral root.	No.of lateral roots.	Length of tap root.	Length of longest lateral root.	No.of lateral roots.
	(cm)	(cm)		(cm)	(cm)		(cm)	(cm)	
Large	12.66	4.09	33.91	17.76	6.24	39.88	22.49	11.65	54.66
Medium	12.94	3.49	31.66	17.28	7.66	42.33	19.24	9.24	53.66
Small	13.17	3.48	32.77	17.24	6.75	37.33	19.26	11.05	51.00
F-Value	0.18	3.52**	0.52^{NS}	0.106^{NS}	0.61^{NS}	9.80**	2.96^{NS}	0.68^{NS}	1.15^{NS}
CD(0.05)	1.73	0.55	4.59	2.63	2.74	2.37	3.23	4.48	5.23

NS Not significant
** Significant at 1% level.

Table 13c. Root growth parameters of cocoa seedlings at various intervals sown in different months. March sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root.	Length of longest lateral root.	No.of lateral roots.	Length of tap root.	Length of longest lateral root.	No.of lateral roots.	Length of tap roots.	Length of longest lateral root.	No.of lateral roots.
	(cm)	(cm)		(cm)	(cm)		(cm)	(cm)	
Pedicel end.	12.16	3.51	30.88	10.34	5.98	39.55	20.7	11.66	53.7
Middle	13.72	4.06	33.24	17.66	7.46	41.33	20.20	10.84	53.7
Distal end.	12.89	3.49	34.22	16.29	7.21	38.66	20.1	9.44	51.7
P-Value	1.80^{NS}	3.08^{NS}	1.22^{NS}	1.39^{NS}	0.74^{NS}	2.89^{NS}	0.096^{NS}	0.55^{NS}	0.43^{NS}
CD(0.05)	1.73	0.55	4.59	2.63	2.74	2.37	3.23	4.48	5.23

NS Not significant.

in any of the root characters at any of the intervals.

(iii) Dry weight.

The mean dry weight of the shoot and the root and the total dry weight are presented in Table 14a and Figure 3.

There was significant difference in the dry weight of the shoot and the total dry weight on the 90th day after germination while there was no significant difference in the mean dry weight of the root at any of the intervals of recording. On the 30th day after germination the dry weight of the shoot varied from 1105.33 mg (T_7) to 1568 mg (T_5) while that of the root varied from 228.16 mg (T_4) to 398 mg (T_5). The total dry weight ranged from 1439.33 mg (T_7) to 1966 mg (T_5).

The maximum dry weight of the shoot obtained was 1678.66 mg (T_1) and the minimum 2462 mg (T_6) while that of the root varied from 360 mg (T_7) to 526 mg (T_2). The total dry weight ranged from 2116.66 mg (T_1) to 2693.32 mg (T_4).

The dry weight of the shoot on the 90th day after germination was significantly higher for T_2(4924.66 mg) which was on par with T_6 and T_7. The lowest dry weight was recorded for T_4(2614.66 mg). The dry weight of the root varied from 490.33 mg (T_4) to 836.66 mg (T_8). The total dry weight for the same period was significantly

Table 14a. Dry weight of cocoa seedlings at various intervals sown in different months. March sowing.

Days after germination.	30th day			60th day			90th day		
Treatment	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
T_1-LP	1238.66	265.66	1504.33	1678.66	438	2116.66	2820.66	716	3536.66
T_2-LM	1377	262	1639	1988.66	526	2514.66	4924.66	872	5796.66
T_3-LD	1368	300.66	1668.66	1713.33	439.33	2152.66	2872	622	3494.00
T_4-MP	1360.11	228.16	1539.27	2236.66	456.66	2693.32	2614.66	490.33	3105.00
T_5-MM	1568	398	1966	2031	453.66	2484.66	2748.66	498	3246.66
T_6-MD	1216	275.33	1493.33	2262	387	2649.00	3316	593.33	3909.33
T_7-SP	1105.33	334	1439.33	1873.33	360	2233.33	3919.33	542	4461.33
T_8-SM	1427.66	282.16	1709.82	1996.66	461.33	2458.00	4632	886.66	5518.66
T_9-SD	1505.33	255.33	1760.66	2125.33	430.66	2556.00	3730.66	795.33	4526.00
F-Value	1.62 NS	2.55 NS	1.34 NS	1.24 NS	1.70 NS	1.43 NS	3.62 *	2.04 NS	3.24*
CD(0.05)	347.9	119.15	401.01	430.41	91.62	471.79	1097.55	252.39	1268.80

NS Not significant.
* Significant at 5% level.

higher for T_2 (5796.66 mg). T_2 was on par with T_8. The lowest total dry weight was obtained for T_4 (3105 mg). Taking into account the effect of pod size only (Table 14b) the dry weight of the shoot was significantly higher for 'medium' on the 60th day and for 'small' on the 90th day while that of the root was significantly higher for 'small' only on the 90th day. The total dry weight did not show any significant variation at any of the intervals.

Considering the effect of seed position alone (Table 14c) the dry weight of the shoot was significantly higher for 'middle' on the 90th day only while that of the root was significantly higher for 'middle' on the 60th day only. There was no significant difference in the total dry weight at any of the intervals of recording.

1.4.5 April sowing.

(i) Vegetative growth.

The data on the height, girth and the number of leaves are presented in Table 15a.

There was no significant difference in the height, girth or number of leaves at any of the intervals. The mean height of the seedlings ranged from 13.74 cm (T_7) to 16.43 cm (T_3) on the 15th day after germination. The girth at the same period varied from 1.36 cm (T_6) to 1.46 cm (T_2 and T_4) and the number of leaves produced ranged from 3.70 (T_2 to 4.33 (T_5). The maximum height recorded on the

Table 14b. Dry weight of cocoa seedlings at various intervals sown in different months. March sowing.

Days after germination	30th day			60th day			90th day		
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
Large	1327.88	276.11	1604.00	1793.55	467.78	2261.33	3539.11	735.66	4275.77
Medium	1302.03	300.5	1602.53	2176.55	432.44	2609.00	2893.11	527.22	3420.33
Small	1346.11	290.5	1636.61	1998.44	417.33	2415.77	4094.00	741.33	4835.33
F-Value	0.16^{NS}	0.28^{NS}	0.25^{NS}	5.25*	1.55^{NS}	3.61*	7.94 **	6.21 **	8.35**
CD(0.05)	306.85	68.79	231.52	268.49	52.00	272.33	633.67	145.72	732.54

NS Not significant.
* Significant at 5% level.
** Significant at 1% level.

Table 14c. Dry weight of cocoa seedlings at various intervals sown in different months. March sowing.

Days after germination	30th day			60th day			90th day		
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
Pedicel end	1234.70	275.94	1510.64	1929.55	418.22	2347.77	3118.22	582.77	3701.00
Middle	1437.55	314.05	1771.61	2005.44	480.33	2485.77	4101.77	752.22	4854.00
Distal end	1363.77	277.11	1640.88	2033.55	419.00	2452.55	3306.22	670.22	3976.44
F-Value	2.73^{NS}	0.87^{NS}	2.80^{NS}	0.41^{NS}	4.49*	0.61^{NS}	5.99*	2.98^{NS}	5.96*
CD(0.05)	200.85	68.79	231.52	248.49	52.90	272.38	633.67	145.72	732.54

NS Not significant
* Significant at 5% level.

Table 15a. Shoot growth parameters of cocoa seedlings at various intervals sown in different months. April sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1-LP	14.32	1.40	4.23	16.23	1.49	5.63	19.57	1.51	7.33
T_2-LM	13.98	1.46	3.76	16.72	1.48	5.93	21.09	1.96	7.06
T_3-LD	16.43	1.42	4	17.98	1.44	5.53	19.86	1.6	6.6
T_4-MP	15.82	1.46	4.13	17.01	1.49	5.73	17.64	1.50	6.6
T_5-MM	15.80	1.44	4.33	21.16	1.53	5.26	21.37	1.55	7.4
T_6-MD	16.20	1.36	3.93	18.84	1.45	6.2	19.2	1.46	6.2
T_7-SP	13.74	1.40	4.13	18.19	1.45	5.23	19.33	1.51	5.76
T_8-SM	16.12	1.40	4	20.29	1.49	6.8	20.58	1.50	7.93
T_9-SD	15.24	1.41	4.2	17.23	1.47	6.56	17.84	1.48	7.4
F-Value	0.35^{NS}	1.16^{NS}	0.94^{NS}	0.31^{NS}	0.29^{NS}	1.25^{NS}	0.42^{NS}	0.96^{NS}	0.77^{NS}
CD(0.05)	3.43	0.09	0.635	7.24	0.11	1.56	4.09	0.12	2.49

NS Not significant.

Table 15a. Continued

Days after germination	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1-LP	22.83	1.57	8.06	28.3	2.02	8.8	28.49	2.12	10.66
T_2-LM	23.12	1.65	9.6	27.12	2.06	9.73	30.27	2.09	10.73
T_3-LD	22.11	1.60	7.6	25.43	1.92	10.33	27.41	2.06	10.8
T_4-MP	19.86	1.66	7.46	20.50	1.66	8.96	27.77	2.1	11.4
T_5-MM	21.51	1.60	8.26	24.7	1.93	10.06	27.49	2.04	11.46
T_6-MD	20.68	1.57	6.66	22.49	1.6	9.06	26.72	2.01	10.86
T_7-SP	19.79	1.59	7.51	21.85	1.75	9.76	27.57	2.07	10.4
T_8-SM	22.48	1.56	8.93	25.96	1.91	10.46	26.55	2.04	11.93
T_9-SD	22.56	1.62	8.06	23.00	1.8	8.23	20.85	2.07	11.2
F-Value	0.49^{NS}	0.30^{NS}	0.27^{NS}	0.42^{NS}	0.60^{NS}	1.84^{NS}	0.46^{NS}	0.09^{NS}	0.16^{NS}
CD(0.05)	3.73	0.24	2.31	7.56	0.29	2.00	5.84	0.23	3.41

NS Not significant.

30th day after germination was 21.16 cm (T_5) and the minimum 16.42 cm (T_1). The maximum girth produced for the same period was 1.53 (T_5) and the minimum 1.44 cm (T_3). The number of leaves produced varied from 5.23 (T_7) to 6.8(T_8).

On the 45th day after germination the height of the seedling varied from 17.64 cm (T_4) to 21.37 cm (T_5) while the girth ranged from 1.46 cm (T_6) to 1.6 cm (T_3). The number of leaves produced at the same period varied from 5.76 (T_7) to 7.93 (T_8).

On the 60th day after germination the maximum height produced was 23.12 cm (T_2) and the minimum 19.79 cm (T_7). The maximum girth obtained at the same period was 1.66 cm (T_4) and the minimum 1.56 cm (T_3). The number of leaves produced ranged from 7.46 (T_4) to 9.6 (T_2).

On the 75th day after germination the seedling height varied from 20.5 cm (T_4) to 28.3 cm (T_1) while the girth varied from 1.6 cm (T_6) to 2.06 cm (T_2). The number of leaves produced for the same period ranged from 8.23(T_9) 10.86 (T_5). The seedling height on the 90th day varied from 26.55 cm (T_8) to 30.27 cm (T_2). The girth for the same period ranged from 2.01 cm (T_6) to 2.12 cm (T_1) while the number of leaves varied from 10.4 (T_7) to 11.93 (T_8).

Considering the effect of pod size alone (Table 15b) there was no significant difference in the height and number of leaves of any of the intervals of recording while the girth was significantly higher for 'large' on the 7th day.

Table 15b. Shoot growth parameters of cocoa seedlings at various intervals soon in different months. April sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Large	15.57	1.43	4.00	17.04	1.47	5.70	20.17	1.55	7.00
Medium	15.94	1.42	4.13	19.00	1.49	5.73	19.40	1.50	6.73
Small	15.04	1.40	4.11	18.56	1.47	6.20	19.25	1.50	7.03
F-Value	0.46^{NS}	0.44^{NS}	0.31^{NS}	0.61^{NS}	0.23^{NS}	0.84^{NS}	0.38^{NS}	1.61^{NS}	0.11^{NS}
CD(0.05)	1.98	0.05	0.36	4.18	0.06	0.90	2.36	0.07	1.43

NS Not significant.

Table 15b. Continued.

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Large	22.69	1.61	8.42	26.95	2.00	9.62	30.73	2.09	10.60
Medium	20.68	1.61	7.46	23.56	1.73	9.90	27.32	2.05	11.34
Small	21.61	1.59	8.17	23.60	1.82	9.48	27.65	2.06	11.31
F-Value	1.86^{NS}	0.05^{NS}	1.21^{NS}	2.43^{NS}	5.97*	0.28^{NS}	0.41^{NS}	0.24^{NS}	0.69^{NS}
CD(0.05)	2.18	0.14	1.33	4.36	0.16	1.15	3.37	0.13	1.39

NS Not significant

* Significant at 5% level.

Taking into account the effect of seed position alone (Table 15c) there was no significant differences in any of the shoot characters at any of the intervals.

(ii) Root growth.

The data on the mean length of the tap root, the longest lateral root and the number of lateral roots are presented in Table 16a.

There was no significant difference in the length of the tap root and the number of lateral roots at any of the intervals, while there was significant variation in the length of the longest lateral root on the 90th day.

On the 30th day after germination the length of the tap root varied from 11.6 cm (T_6) to 13.84 cm (T_9). The longest lateral root varied in length at the same period from 3.22 cm (T_1) to 5.25 cm (T_5). The largest mean number of lateral roots was produced in T_2 (38) and the smallest number in T_7 (28.33).

On the 60th day after germination the length of the tap root varied from 12.76 cm (T_6) to 14.71 cm (T_4) while the length of the longest lateral root varied from 4.45 cm (T_1) to 5.68 cm (T_5). The number of lateral roots for the same period varied from 34 (T_5) to 40.66 (T_2).

The length of the tap root ranged from 14.63 cm (T_7) to 13.07 cm (T_6) on the 90th day after germination. The

Table 15c. Shoot growth parameters of coco seedlings at various intervals sown in different months. April sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Radicel end.	14.63	1.42	4.16	17.20	1.48	5.53	18.84	1.51	6.56
Middle	15.97	1.43	4.03	19.39	1.50	6.00	21.01	1.54	7.46
Distal end.	15.96	1.40	4.04	18.02	1.45	6.10	18.96	1.51	6.73
F-Value	1.32^{NS}	0.75^{NS}	0.34^{NS}	0.61^{NS}	1.07^{NS}	0.93^{NS}	2.34^{NS}	0.41^{NS}	0.97^{NS}
CD(0.05)	1.98	0.05	0.36	4.18	0.06	0.90	2.36	0.07	1.43

NS Not significant

Table 15c. Continued.

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
Pedicel end.	20.83	1.61	7.60	23.55	1.81	9.17	27.94	2.09	10.95
Middle	22.37	1.60	8.93	25.92	1.97	10.35	29.10	2.06	11.37
Distal end.	21.78	1.60	7.44	23.64	1.77	9.47	27.66	2.05	10.82
F-Value	1.12^{NS}	0.11^{NS}	3.16^{NS}	0.83^{NS}	3.34^{NS}	2.46^{NS}	0.03^{NS}	0.32^{NS}	0.38^{NS}
CD(0.05)	2.18	0.14	1.33	4.36	0.16	1.15	3.37	0.12	1.39

NS Not significant.

Table 16a. Root growth parameters of cocoa seedlings at various intervals sown in different months. April sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.
T_1-LD	13.4	3.22	35.66	14.22	4.45	45.66	16.70	4.54	36.33
T_2-LM	13.37	4.30	38	14.19	5.63	40.66	15.79	7.05	41
T_3-LD	13.4	4.49	34.66	14.34	5.33	35.5	16.96	10.19	36.33
T_4-MD	12.42	4.03	34.66	14.71	5.59	37.33	14.76	6.69	39.66
T_5-MM	12.88	5.25	30.66	14.00	5.68	34	15.29	6.98	36.33
T_6-MD	11.6	4.57	33.66	12.76	4.65	35	10.07	4.93	35.66
T_7-SD	12.91	4.69	28.33	14.34	4.98	36.33	14.63	5.22	37.33
T_8-SM	12.08	4.34	34.66	14.59	5.22	36.66	17.56	6.32	37
T_9-SD	13.84	4.18	36	14.44	5.00	36.33	16.15	5.59	37
F-Value	0.23^{NS}	1.86^{NS}	2.94^{NS}	0.32^{NS}	0.68^{NS}	1.16^{NS}	0.64^{NS}	3.62*	2.03^{NS}
CD(0.05)	4.67	1.16	5.61	3.16	1.74	6.11	4.91	3.06	4.46

NS Not significant
* Significant at 5% level.

length of the longest lateral root was significantly higher for T_3(10.19 cm). The minimum length was observed for T_1 (4.54 cm). The number of lateral roots for the same period varied from 35.66 (T_6) to 41 (T_2).

Considering the main effects of pod size and seed position separately (Table 16b and 16c) there was no significant difference in any of the root characters studied at any of the intervals.

(iii) Dry weight.

The mean dry weight of the shoot and the root and the total dry weight are presented in Table 17a.

There was no significant difference in the dry weight of the shoot and the total dry weight at any of the intervals of recording. The dry weight of the root showed significant variation on the 60th day only.

On the 30th day after germination the dry weight of the shoot varied from 640 mg (T_6) to 955.33 mg(T_5) while that of the root ranged from 117.33 mg (T_4) to 223.33 mg (T_8). The total dry weight for the same period varied from 772.66 mg (T_6) to 1087 mg (T_5).

On the 90th day after germination the dry weight of the shoot varied from 1325.33 mg (T_4) to 2769.33 mg (T_9) while that of the root ranged from 221.33 mg (T_6) to 716 mg (T_8). The total dry weight for the same period varied from 1548 mg (T_6) to 3426 mg (T_9).

Table 16b. Root growth parameters of cocoa seedlings at various intervals sown in different months. April sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of laterals root.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of laterals roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No. of lat laterals root.
Large	13.39	4.00	36.11	14.22	5.15	37.27	16.48	7.26	37.0
Medium	12.30	4.62	33.00	13.02	5.31	35.44	16.04	6.20	37.2
Small	13.94	4.40	33.00	14.45	5.03	36.44	16.11	5.70	37.1
F-Value	0.36^{NS}	1.89^{NS}	2.71^{NS}	0.26^{NS}	0.16^{NS}	0.39^{NS}	0.06^{NS}	1.78^{NS}	0.23^{N}
CD(0.05)	2.70	0.67	3.24	1.82	1.00	3.52	2.84	1.76	2.57

NS Not significant.

Table 16c. Root growth parameters of coca seedlings at various intervals sown in different months. April sowing.

Days after germination	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.
Pedicel end.	12.91	3.98	32.00	14.42	4.97	36.44	15.36	5.48	37.77
Middle	12.78	4.63	34.44	14.22	5.51	37.11	16.21	6.78	38.11
Distal end.	12.95	4.41	34.77	13.84	5.01	35.61	17.06	6.90	36.33
F-Value	0.10^{NS}	2.14^{NS}	0.85^{NS}	0.22^{NS}	0.77^{NS}	0.40^{NS}	0.78^{NS}	1.74^{NS}	1.16^{NS}
CD(0.05)	2.70	0.67	3.24	1.02	1.00	3.52	2.84	1.76	2.57

NS Not significant.

Table 17 a. Dry weight of cocoa seedlings at various intervals sown in different months. April sowing.

Days after germination	30th day			60th day			90th day		
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
T_1-LP	717.33	172.33	889.66	1185.33	246.66	1432.00	1672	299.33	1971.33
T_2-LM	752.66	157	909.66	1274.66	254	1528.66	1376.66	339.33	1716.00
T_3-LD	785.33	186.66	972.00	912.66	251.33	1164.00	1366.66	337.66	1704.33
T_4-MP	768	117.33	885.33	1236.66	199.33	1436.00	1325.33	233.33	1558.66
T_5-MM	955.33	131.66	1087.00	1294.66	266	1560.66	1372.66	278	1650.66
T_6-MD	640	132.66	772.66	1250.66	210	1460.66	1326.66	221.33	1548.00
T_7-SP	676.66	171.00	847.66	1133.33	318	1451.33	2047.33	470.66	2518.00
T_8-SM	757	223.33	980.33	1052.66	302	1354.66	2272	716	2988.00
T_9-SD	713.33	210.66	924.00	917.33	218	1135.33	2769.33	656.66	3426.00
F-Value	0.83^{NS}	1.14^{NS}	0.94^{NS}	2.88^{*}	3.08^{NS}	2.36^{NS}	0.50^{NS}	0.36^{NS}	0.43^{NS}
CD(0.05)	290.61	48.32	299.75	172.16	59.42	202.84	1136.04	319.79	1419.19

NS Not significant.
* Significant at 5% level.

Taking into account the effect of pod size alone (Table 17b) there was significant difference on the 60th day when the weight was significantly higher for 'medium' and on the 90th day when the weight for 'small' was significantly higher. The dry weight of the root was significantly higher for 'small' on the 30th, 60th and 90th days after germination. The total dry weight showed significant difference on the 60th day when the weight for 'medium' was significantly higher and on the 90th day when the weight for 'small' was significantly higher.

Considering the effect of seed position by itself (Table 17c) there was significant difference in the dry weights only on the 60th day when the dry weight of the shoot and root, and the total dry weight was significantly higher for 'middle'.

1.5 Size of Containers

A detailed study of the growth characters upto 90 days under varying sizes of polythene bags (30 x 20, 25 x 18 and 23 x 15 cm) was carried out by sowing seeds during December 78, February and March 1979 and the results of the investigations are presented below. The analysis of variance tables for different characters are given in Appendix.

Table 17b. Dry weight of cocoa seedlings at various intervals seen in different months. April sowing.

Days after germination	30th day			60th day			90th day		
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
Large	751.77	172.00	923.77	1124.22	250.66	1374.88	1471.77	325.44	1791.22
Medium	707.77	127.22	915.00	1260.66	225.11	1485.77	1341.55	244.22	1585.77
Small	715.66	201.66	917.32	1034.44	279.33	1313.77	2362.88	614.44	2977.33
F-Value	0.40^{NS}	15.92**	0.10^{NS}	11.59**	5.51*	4.89*	6.34**	9.80**	7.4**
CD(0.05)	167.73	27.90	173.00	99.40	34.30	117.11	655.89	184.63	818.79

NS Not significant.
* Significant at 5% level.
** Significant at 1% level.

Table 17c. Dry weight of cocoa seedlings at various intervals seen in different months. April sowing.

Days after germination	30th day			60th day			90th day		
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
Pedicel end	720.66	153.55	874.21	1185.11	254.66	1439.77	1681.55	334.44	2016.0
Middle	821.66	170.66	992.32	1207.33	274.00	1481.33	1673.77	444.44	2113.2
Distal end	712.88	176.66	889.54	1036.88	326.44	1253.33	1820.00	405.22	2226.1
F-Value	1.15^{NS}	1.63^{NS}	1.22^{NS}	8.65**	4.28*	9.49**	0.14^{NS}	0.80^{NS}	0.14^{N}
CD(0.05)	167.78	27.90	173.00	99.40	34.30	117.11	655.89	184.53	810.79

NS Not significant
* Significant at 5% level
** Significant at 1% level.

1.5.1 Shoot characters.

Data of the height, girth and number of leaves of the seedlings are presented in Tables 18 a to c and Figure 3.

(i) Height.

a) December sowing.

There was significant variation at 1 per cent level between treatments on the 15th & 90th and at 5 per cent level on 90th day after sowing while on the 30th, 45th and 60th day there was no significant variation among treatments. At all these intervals maximum height was recorded for 30 x 20 cm size bag.

On the 15th day T_3 was significantly superior to T_1 but was on par with T_2. The maximum height was 13.5 cm in T_3 and the minimum 5.14 cm in the case of T_1. The maximum height was 20.24 cm for T_3 and the minimum 14.38 cm for T_1 on the 30th day. On the 45th day the maximum height was 21.16 cm for T_3 and the minimum 16.64 cm for T_1. The maximum height was 21.52 cm for T_3 and the minimum 18.36 cm for T_1 on the 60th day.

On the 75th day, T_3 was significantly superior to T_2 and T_1 which were on par. The maximum height 29.9 cm was recorded for T_3 (30 x 20 cm) while the minimum height 18.82 cm was recorded for T_1 (23 x 15 cm).

On the 90th day again T_3 was significantly superior to T_2 and T_1 which were on par. The maximum height recorded

Table 18a. Shoot growth parameters of cocoa seedlings grown in different size of bags. December sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm)	No. of leaves.	Height (cm)	Girth (cm).	No. of leaves.
T_1 (23x15cm)	5.14	1.18	2.40	14.38	1.26	4.20	16.64	1.30	5.00
T_2 (25x18cm)	12.80	1.28	3.40	18.94	1.40	5.40	18.98	1.44	6.80
T_3 (30x20cm)	13.50	1.32	3.80	20.24	1.56	4.60	21.16	1.56	7.00
F-Value	8.89**	1.18^{NS}	9.75**	3.45^{NS}	1.76	2.43^{NS}	2.48^{NS}	1.53^{NS}	3.87^{N}
CD(0.05)	4.79	0.20	0.71	5.10	0.34	1.20	4.42	0.32	1.72

NS Not significant.

** Significant at 1% level.

Table 18a. Continued.

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1 (23x15cm)	18.36	1.32	6.4	18.62	1.40	8.80	19.36	1.64	8.80
T_2 (25x18cm)	19.98	1.48	7.00	20.56	1.72	9.60	21.02	1.96	10.20
T_3 (30x20cm)	21.52	1.66	8.2	29.9	1.92	10.80	30.34	2.18	11.60
F-Value	1.38^{NS}	3.55^{NS}	1.68^{NS}	6.15*	9.05**	1.49^{NS}	7.92**	9.78**	7.00*
CD(0.05)	4.13	0.27	2.17	7.39	0.26	2.54	6.47	0.26	1.63

NS Not significant.
* Significant at 5% level.
** Significant at 1% level.

Table 10b. Shoot growth parameters of cocoa seedlings grown in different sizes of bags. February sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1 (23x15cm)	14.18	1.28	3.80	14.44	1.30	4.40	16.68	1.42	5.00
T_2 (25x18cm)	16.14	1.32	4.00	18.90	1.46	4.40	20.40	1.43	6.80
T_3 (30x20cm)	17.26	1.36	4.00	20.50	1.50	5.20	21.00	1.56	7.00
F-Value	2.96^{NS}	0.75^{NS}	1.00^{NS}	4.76*	4.42*	1.14^{NS}	3.52^{NS}	0.60^{NS}	5.68*
CD(0.05)	2.78	0.14	0.35	4.43	0.15	1.33	3.83	0.27	1.42

NS Not significant.

* Significant at 5% level.

Table 18b. Continued.

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1 (23x15cm)	19.50	1.86	11.00	28.08	2.00	12.40	31.66	2.02	13.40
T_2 (25x18cm)	28.18	1.96	11.60	29.70	2.04	12.60	38.54	2.22	13.60
T_3 (30x20cm)	36.32	2.14	12.40	38.76	2.22	13.40	39.64	2.32	15.40
F-Value	13.26**	2.02^{NS}	1.12^{NS}	3.67^{NS}	1.42^{NS}	0.32^{NS}	2.66^{NS}	2.39^{NS}	2.16^{NS}
CD(0.05)	7.11	0.30	2.04	9.25	0.30	2.85	7.94	0.30	2.30

NS Not significant.

** Significant at 1% level.

Table 18c. Shoot growth parameters of cocoa seedlings grown in different sizes of bags. March sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1 (23x15cm)	14.30	1.20	2.60	14.38	1.28	4.40	15.82	1.36	7.00
T_2 (25x18cm)	16.34	1.30	3.40	18.24	1.48	4.40	20.34	1.50	8.00
T_3 (30x20cm)	17.20	1.32	3.80	18.8	1.56	4.80	21.4	1.80	9.60
F-Value	3.71^{NS}	1.31^{NS}	7.00**	1.98^{NS}	9.75**	0.28^{NS}	3.12^{NS}	5.12*	1.93^{NS}
CD(0.05)	2.38	0.17	0.71	5.26	0.14	1.33	5.16	0.3	2.9

NS Not significant.

* Significant at 5% level.

** Significant at 1% level.

Table 18c. Continued.

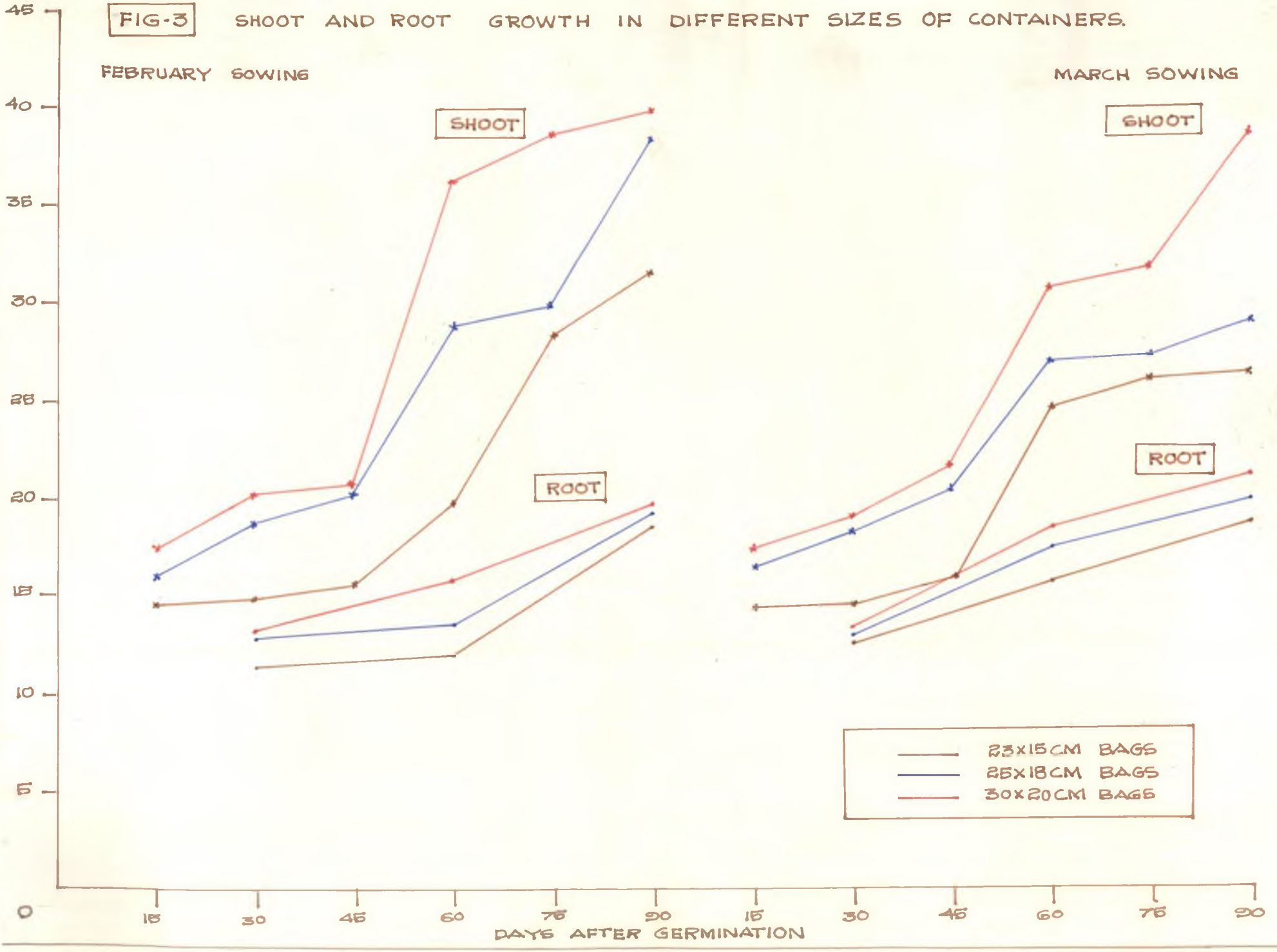
Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1 (23x15cm)	24.6	1.74	9.60	25.98	1.78	9.80	26.30	1.80	11.40
T_2 (25x18cm)	26.86	1.94	10.20	27.08	1.94	11.00	28.82	1.96	11.80
T_3 (30x20cm)	30.60	1.94	11.60	31.28	2.08	11.80	38.62	2.12	12.00
F-Value	0.98^{NS}	0.89^{NS}	0.74^{NS}	1.55^{NS}	1.76^{NS}	3.89*	6.80**	2.02^{NS}	0.18^{NS}
CD(0.05)	9.40	0.37	3.67	6.91	0.34	1.57	7.68	0.34	2.17

NS Not significant.

* Significant at 5% level.

** Significant at 1% level.

FIG-3 SHOOT AND ROOT GROWTH IN DIFFERENT SIZES OF CONTAINERS.



was 30.34 cm for T_3 while the minimum was 19.36 cm for T_1. Bigger size bag showed 58 per cent height than the lowest size bag (23 x 15 cm).

b) February sowing.

Significant variation between treatments was noticed on 30th and 60th day while on the 15th, 45th, 75th and 90th day there was no significant variation. However the maximum height at all intervals was noticed for T_3 (30 x 20 cm).

On the 30th day T_3 was significantly superior to T_1 but was on par with T_2. The maximum height recorded for T_3 was 20.5 cm and the minimum was for T_1 (14.44 cm). On the 60th day T_3 was again significantly superior toT_2 and T_1. The maximum height recorded was 36.22 cm for T_3 and the minimum was 19.5 cm for T_1. Although there was no significant difference on 90th day, the maximum mean height 39.64 cm was recorded in case of T_3 which was about 26 per cent more than the height of T_1.

c) March sowing.

Significant variation among treatments was observed only on the 90th day. At all other intervals the maximum height was recorded for T_3 (30 x 20 cm).

On the 90th day T_3 was significantly superior to T_2 and T_1 which were on par. Under treatment T_3 the mean height

was 38.62 cm which was 46 per cent more than that of T_1 which was the minimum (26.3 cm).

Thus the results clearly indicates the superiority of T_3 (30 x 20 cm) with regard to the height of the seedlings when they are 3 months old.

(ii) Girth.

a) December sowing.

Significant variation at 1 per cent level between treatments was observed on the 75th and 90th day. At all other intervals the maximum girth was shown by seedlings under T_3 (30 x 20 cm).

On the 75th day, T_3 showed significant superiority over T_1 and was on a par with T_2. The maximum girth was observed for T_3 (1.92 cm) and the minimum for T_1 (1.4 cm). Again T_3 showed significant superiority over T_1 on 90th day and was on a par with T_2. The maximum girth observed was for T_3 (2.18 cm) and the minimum for T_1 (1.64 cm).

b) February sowing.

At all the intervals the maximum girth was noticed in T_3 (30 x 20 cm). Significant variation was noticed only on 30th day when T_3 was superior to T_1 and was on par with T_2. The maximum girth observed was 1.5 cm for T_3 and the minimum 1.3 cm for T_1. On 90th day T_3 showed maximum girth (2.32 cm) in this case alone as against 2.02cm in T_1 although the difference was not significant.

c) March sowing.

The maximum girth was observed for T_3 (30 x 20 cm) here also. Significant variation was noticed on 30th and 45th day.

On the 30th day the maximum girth observed was 1.56cm for T_3 and the minimum 1.28 cm for T_1. The maximum girth observed was 1.8 cm for T_3 and the minimum 1.36 cm for T_1 on 45th day. On 90th day T_3 showed maximum girth (2.12 cm) in this case also as against 1.8 cm in T_1.

The results showed that T_3 (30 x 20 cm) showed superiority in respect of the girth of the seedling. The variation in girth was 33 per cent, 15 and 16 per cent higher in case of large size bags during December, February and March sowing.

(iii) Number of leaves.

a) December sowing.

The highest number of leaves was recorded for T_3 (30 x 20 cm) and the minimum for T_1 (23 x 15 cm) at all the intervals. Significant variation was observed on the 15th day and on the 90th day.

b) February sowing.

At all the intervals the highest number of leaves was recorded for T_3 (30 x 20 cm). Significant variation was observed only on the 45th day when T_3 was found superior to T_1 and it was on par with T_2. The maximum mean number

observed was 7 for T_3 and the minimum 5 for T_1. On 90th day the mean number of leaves was 15.4 in case of T_3 and 13.4 in case of T_1.

c) March sowing.

The highest number was noticed for T_3 (30 x 20 cm) at all the intervals. There was significant variation between treatments only on 15th day, when T_3 was found superior to T_1 and was on a par with T_2. The highest mean number was 3.8 for T_3 and the lowest 2.6 for T_1. On 90th day the T_3 showed a mean number of 12 leaves as against 11.4 in case of T_1.

In case of height, girth and number of leaves the bigger sized bags (30 x 20 cm) was superior in all the three months (December, February and March). When comparing the growth parameter among the three months February was found to be the best for sowing for better heights, girth and for more number of leaves. This is closely followed by March. The February sowing has got an advantage that the seedlings will be ready by the middle of May with a height of around 40 cm and this is the congenial period for planting cocoa under Kerala conditions.

1.5.2 Root characters.

The length of the tap root length of the longest lateral root and the number of lateral roots are given in Table 19 a to c.

Table 19a. Root growth parameters of cocoa seedlings grown in different sizes of bags. December sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral root
T_1 (23x15cm)	12.32	2.78	17.20	13.76	4.38	36.00	15.26	4.86	54.0
T_2 (25x18cm)	12.70	3.30	23.00	15.30	5.70	44.00	16.00	7.26	71.0
T_3 (30x20cm)	13.52	3.70	23.60	16.10	4.06	55.00	16.38	11.40	73.0
F-Value	0.43^{NS}	1.39^{NS}	24.98**	1.18^{NS}	0.77^{NS}	8.53**	0.11^{NS}	5.11*	6.11
CD(0.05)	2.39	1.20	2.17	3.36	2.33	10.06	7.9	4.50	13.01

NS Not significant.

* Significant at 5% level.

** Significant at 1% level.

Table 19b. Root growth parameters of cocoa seedlings grown in different sizes of bags. February sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral root.
T_1 (23x15cm)	11.32	2.78	16.80	11.94	3.42	38.00	19.56	6.46	44.0
T_2 (25x18cm)	12.94	3.32	23.00	14.64	6.16	39.00	19.12	7.36	47.0
T_3 (30x20cm)	13.30	3.76	23.60	15.60	7.28	39.00	19.46	10.52	49.0
F-Value	1.67^{NS}	1.85^{NS}	18.48**	1.55^{NS}	4.12*	0.04^{NS}	0.08^{NS}	2.64^{NS}	0.66^{N}
CD(0.05)	2.51	1.11	2.69	4.90	3.01	8.15	4.87	4.04	9.49

NS Not significant.
* Significant at 5% level.
** Significant at 1% level.

Table 19c. Root growth parameters of cocoa seedlings grown in different sizes of bags. March sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral root.
T_1 (23x15cm)	12.54	2.78	17.60	15.48	4.36	34.00	18.58	6.80	35.00
T_2 (25x18cm)	12.70	2.98	23.00	17.16	7.84	37.00	19.80	8.64	49.00
T_3 (30x20cm)	13.38	3.58	23.20	18.52	8.50	40.00	21.00	8.96	51.00
F-Value	0.29^{NS}	2.01^{NS}	18.92**	0.74^{NS}	5.99*	0.51^{NS}	0.26^{NS}	0.31^{NS}	2.69^{NS}
CD(0.05)	2.55	0.9	2.25	5.42	2.79	12.89	7.29	6.42	16.35

NS Not significant.

* Significant at 5% level.

** Significant at 1% level.

(1) Length of tap root.

a) December sowing.

No significant variation between treatments was observed. The maximum value was however obtained for T_3 (30 x 20 cm) on 30th, 60th and 90th days. The mean length of tap root mean number of laterals and the length of longest lateral root were 16.38 cm, 73 and 11.4 cm respectively in case of T_3 and on 90th day.

b) February sowing.

The maximumv value was obtained for T_3 (30 x 20 cm) at all intervals. But there was no significant difference between treatments at any of the intervals. The tap root, length, number of laterals and length of longest laterals were 19.46, 49 and 10.52 cm respectively on 90th day.

c) March sowing.

The longest tap root was noticed at all intervals for T_3 (30 x 20 cm). No significant difference between treatments was however obtained. On 90th day the tap root length was 21 cm and the number of laterals was 51 and the length of lateral was 8.96 cm in case of T_3.

The results thus indicate that, though no significant difference was observed between treatments, the length of the tap root was maximum in 30 x 20 cm size bags. The maximum root growth was observed in February and March sowing which also indicated the desirability of sowing seeds in February

or in March rather than in December.

(ii) Length of the longest lateral roots.

a) December sowing.

The longest lateral root was obtained for T_3 at all intervals. However significant variation between treatments was noticed only on the 90th day. The maximum length 11.4 cm was for T_3 (30 x 20 cm) and the minimum 4.86 cm for T_1 (23 x 15 cm).

b) February sowing.

Significant difference at 5 per cent level between treatments was observed on 60th day. T_3 was superior to T_1 and was on a par with T_2. The length of the longest lateral root was maximum for T_3 (30 x 20 cm) which was 7.28 cm and minimum for T_1 (23 x 15 cm) which was 3.42 cm. However the longest lateral roots were observed for T_3 on the 30th (3.76 cm) and 90th day (10.52) as well.

c) March sowing.

Here also significant difference at 5 per cent level between treatments was obtained on the 60th day when T_3 (30 x 20 cm) was found superior to T_1 and was on a par with T_2. The length 8.5 cm was maximum for T_3 and minimum for T_1 (4.36 cm). At other intervals also the longest length was observed for T_3 (30 x 20 cm). From the results it can there be said that the longest lateral roots are seen in cocoa seedlings grown in 30 x 20 cm sized bags.

(iii) Number of lateral roots.

a) December sowing.

There was significant variation between treatments on 30th, 60th and 90th day. At all these intervals the maximum value was in T_3 and the minimum in T_1. On the 30th day T_3 was significantly superior to T_1 and on a par with T_2. The largest number of lateral roots (23.6) were produced in 30 x 20 cm bags and the smallest number (17.2) in 23 x 15 cm bags. On the 60th day T_3 was superior to T_2 and T_1 which were on a par. The largest number was noticed for in T_3 (55) and the smallest number in T_1(36). The same treatment was superior to T_1 and was on a par with T_2. The largest number of lateral roots were obtained in T_3 (73) and the smallest for T_1 (54).

b) February sowing.

Significant variation between treatments was obtained only on 30th day where T_3 was superior to T_1 and was on a par with T_2. The number of lateral roots were highest for T_3 (23.6)and lowest for T_1 (16.8). On the 60th and 90th day also the number of lateral roots was highest in the care of seedlings grown in 30 x 20 cm bags.

c) March sowing.

Here also significant variation was obtained between treatments only at the 30th day. T_3 was found superior to T_1 and was on a par with T_2. The highest number of lateral roots were obtained in T_3(23.2) and the lowest number in T_1 (17.6).

Table 20a. Dry weight of cocoa seedlings grown in different sizes of bags. December sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
T_1 (23x15cm)	891	254	1145	1580	280	1860	1610	284	1894
T_2 (25x18cm)	855	292	1147	1680	354	2034	1680	371	2051
T_3 (30x20cm)	722	335	1057	1090	387	2277	1960	480	2440
F-Value	3.10^{NS}	0.43^{NS}	0.49^{NS}	0.72^{NS}	3.13^{NS}	1.31^{NS}	0.53^{NS}	8.96**	1.16^{NS}
CD(0.05)	155.71	183.70	224.34	572.09	95.39	562.47	781.81	101.06	801.19

NS Not significant.

** Significant at 1% level.

Table 20b. Dry weight of cocoa seedlings grown in different size of bags. February sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
T_1 (23x15cm)	720	280	1000	1494	285	1779	1604	346	1950
T_2 (25x18cm)	848	358	1206	1660	360	2020	1856	364	2220
T_3 (30x20cm)	876	376	1252	1862	470	2332	1916	480	2396
F-Value	3.13^{NS}	1.72^{NS}	6.28*	0.89^{NS}	4.41*	1.72^{NS}	0.43^{NS}	1.72^{NS}	0.73^{NS}
CD(0.05)	144.86	119.74	164.99	598.80	136.54	553.54	775.42	170.76	805.94

NS Not significant.

* Significant at 5% level.

Table 20c. Dry weight of cocoa seedlings grown in different sizes of bags. March sowing.

Days after germination.	30th day			60th day			90th day		
Treatments	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
T_1 (23x15cm)	721	246	967	1275	292	1567	1798	332	2130
T_2 (25x18cm)	848	308	1156	1524	334	1843	2046	370	2416
T_3 (30x20cm)	855	366	1221	1630	366	1996	2116	386	2502
F-Value	3.5^{NS}	1.14^{NS}	2.85^{NS}	0.8^{NS}	0.98^{NS}	1.18^{NS}	0.30^{NS}	0.61^{NS}	0.42^{NS}
CD(0.05)	124.2	172.73	235.60	624.16	115.52	616.11	938.78	108.76	919.36

NS Not significant.

On the 60th and 90th day as well as the number of lateral roots were highest in the case of seedlings grown in 30 x 20 cm bags. Thus the results show that seedlings grown in 30 x 20 cm bags have the largest number of lateral roots.

1.5.3 Dry weight.

Dry weight of the shoot, root and the total dry weight are presented in Table 20 a,b,c. The analysis of variance tables are given in Appendix.

(i) Dry weight of shoot.

There was no significant difference between treatments in case of December, January and February sowing. The highest values were however obtained at all intervals in the case of T_3 (30 x 20 cm). The values for 90th day were 1960 mg in December, 1916 mg in January and 2116 mg in February. The highest values in all the three months were obtained for T_3.

Thus from the tables it is clear that the dry weight of shoot was highest for seedlings grown in 30 x 20 cm bags.

(ii) Dry weight of root.

a) December sowing.

Significant variation between treatments was observed on 90th day. T_3 was superior to T_2 and T_1 which were on a par. The dry weight of the root for T_3 was 480 mg and

that for T_1 284 mg. On the 30th and 60th day also the highest dry weight were obtained for seedlings grown in 30 x 20 cm bags.

b) February sowing.

On 30th and 90th day there was no significant variation between treatments though the highest weights were obtained for T_3.

On the 60th day T_3 was found significantly superior to T_1 and on a par with T_1. The highest weight was obtained for T_3 (470 mg) and the lowest weight for T_1 (285 mg).

c) March sowing.

There was no significant variation between treatments though the highest weights were seen in T_3 at all the intervals.

Thus it can be clearly seen that the dry weight of root was highest for seedlings grown in 30 x 20 cm bags. Among the different periods of sowing the maximum dry weight of the root was observed in December and February (480 mg) which was 386 mg in case of March sowing, when the seedlings were 90 days old.

(iii) Total dry weight.

a) December sowing.

The highest weights were obtained at all intervals for T_3 (30 x 20 cm) though there was no significant difference.

b) February sowing.

There was significant variation in total dry weight on 30th day. T_3 was superior T_1 and was on a par with T_2. The highest total dry weight was obtained for T_3 (1252 mg) and the lowest for T_1 (1000 mg).

On the 60th and 90th day also the highest total dry weight was obtained for T_3 though there was no significant difference.

c) March sowing.

The total dry weight was highest for T_3 on the 30th 60th and 90th days though there was no significant difference.

Thus the results show that the total growth as measured by dry weight of shoots and roots was maximum in case of T_3 (30 x 20 cm) and among the months of sowing the maximum observed in March sowing (2502 mg) followed by December (2440 mg) and February (239.6 mg). However maximum root growth by way of dry weight was observed in case of February and December sowing (480 mg each) as against 386 mg in March.

1.6 Potting Medium

The results of the detailed study of the growth characters of cocoa seedlings in different potting mixtures are presented below. The analysis of variance tables for the different characters are given in Appendix.

1.6.1 Shoot characters.

The height, girth and number of leaves of the cocoa seedlings are given in the Table 21a to c and Figure 4.

(i) Height.

(a) December sowing.

The maximum height was in T_2 (1:1:2 mixture) at all intervals. Significant difference between treatments was obtained at 1 per cent level on the 30th day, at 5 per cent level on 45th and 75th day. At these intervals T_2 was significantly superior to T_3 (soil) and was on a par with T_1. On 30th day, the maximum height was 19.16 cm in T_2 and the minimum 14.08 in T_3. On the 45th day again the maximum height was 20.5 cm in T_2 and the minimum 17.02 cm in T_3. The maximum height on 75th day was 27.54 cm in T_2 and the minimum 18.54 cm in T_3. On the 90th day the maximum height was 34.18 cm in T_2 and the minimum 26.16 cm in T_3.

b) February sowing.

The maximum height was obtained for T_2 at all the intervals. There was significant variation between the treatments at 5 per cent level on the 15th and at 1 per cent level on the 30th day. On the 15th day, T_2 was significantly superior to T_1 and T_3 which were on par. The maximum height was 18.38 cm for T_2 and the minimum 14.16 cm for T_3. On the 30th day T_2 was significantly superior to T_3 and was on par with T_1. The height 19.36 cm for T_2 was the

Table 21a. Shoot growth parameters of cocoa seedlings grown in different media. December sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1 (1:1:1)	14.30	1.24	4.20	18.90	1.34	4.20	19.16	1.62	7.00
T_2 (1:1:2)	14.80	1.32	4.40	19.16	1.34	4.60	20.50	1.72	7.40
T_3 (Soil)	14.30	1.06	4.00	14.80	1.32	4.20	17.02	1.5	6.60
F-Value	0.06^{NS}	1.05^{NS}	1.20^{NS}	7.59^{**}	0.06^{NS}	0.19^{NS}	4.50^{*}	1.59^{NS}	0.58^{NS}
CD(0.05)	3.39	0.40	0.56	3.19	0.11	1.63	2.54	0.26	1.61

NS Not significant.

* Significant at 5% level.

** Significant at 1% level.

Table 21a. Continued.

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1 (1:1:1)	23.22	2.06	7.20	25.36	2.06	8.20	32.98	2.08	12.60
T_2 (1:1:2)	23.88	2.14	9.80	27.54	2.16	11.20	34.18	2.22	13.80
T_3 (Soil)	19.86	1.76	7.00	20.54	1.88	7.20	26.16	1.90	9.80
F-Value	1.96^{NS}	5.05*	12.62**	6.8*	2.45^{NS}	3.49^{NS}	7.32**	0.76^{NS}	2.98^{NS}
CD(0.05)	4.74	0.27	1.36	554	0.27	3.43	4.92	0.56	3.66

NS Not significant.

* Significant at 5% level.

** Significant at 1% level.

Table 21b. Shoot growth parameters of cocoa seedlings grown in different media. February sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1 (1:1:1)	15.96	1.34	4.30	17.43	1.40	4.30	19.16	1.62	6.30
T_2 (1:1:2)	13.33	1.34	4.40	19.36	1.44	4.40	20.40	1.72	7.40
T_3 (Soil)	14.16	1.33	3.60	15.3	1.38	4.20	17.10	1.5	6.00
F-Value	5.73*	0.06[NS]	0.25[NS]	13.06**	0.93[NS]	0.06[NS]	3.19[NS]	2.04[NS]	0.56[NS]
CD(0.05)	2.72	0.14	0.71	1.60	0.09	1.18	2.07	0.33	1.12

NS Not significant.

* Significant at 5 % level.

** Significant at 1 % level.

Table 21b. Continued.

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1 (1:1:1)	26.08	1.64	11.20	28.22	2.02	13.20	40.58	2.12	13.60
T_2 (1:1:2)	25.16	1.74	12.20	29.26	2.14	14.00	41.24	2.24	14.60
T_3 (Soil)	22.00	1.59	8.40	25.10	1.92	11.00	37.80	1.94	12.20
F-Value	0.51^{NS}	0.90^{NS}	2.74^{NS}	0.29^{NS}	0.90^{NS}	2.54^{NS}	0.18^{NS}	1.64^{NS}	1.15^{NS}
CD(0.05)	10.18	0.26	3.66	12.29	0.35	2.94	13.15	0.36	3.44

NS Not significant.

Table 21c. Shoot growth parameters of cocoa seedlings grown in different media, March sowing.

Days after germination.	15th day			30th day			45th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1 (1:1:1)	14.30	1.24	4.20	17.46	1.34	4.20	18.12	1.54	6.80
T_2 (1:1:2)	14.70	1.30	4.40	20.5	1.34	4.60	21.10	1.72	7.60
T_3 (Soil)	14.30	1.08	4.00	14.18	1.32	4.20	16.08	1.50	5.80
F-Value	0.05^{NS}	0.9^{NS}	1.20^{NS}	10.9**	0.06^{NS}	0.19^{NS}	1.66^{NS}	0.79^{NS}	0.80^{NS}
CD(0.05)	3.06	0.36	0.86	2.96	0.14	1.60	5.07	0.40	3.10

NS Not significant

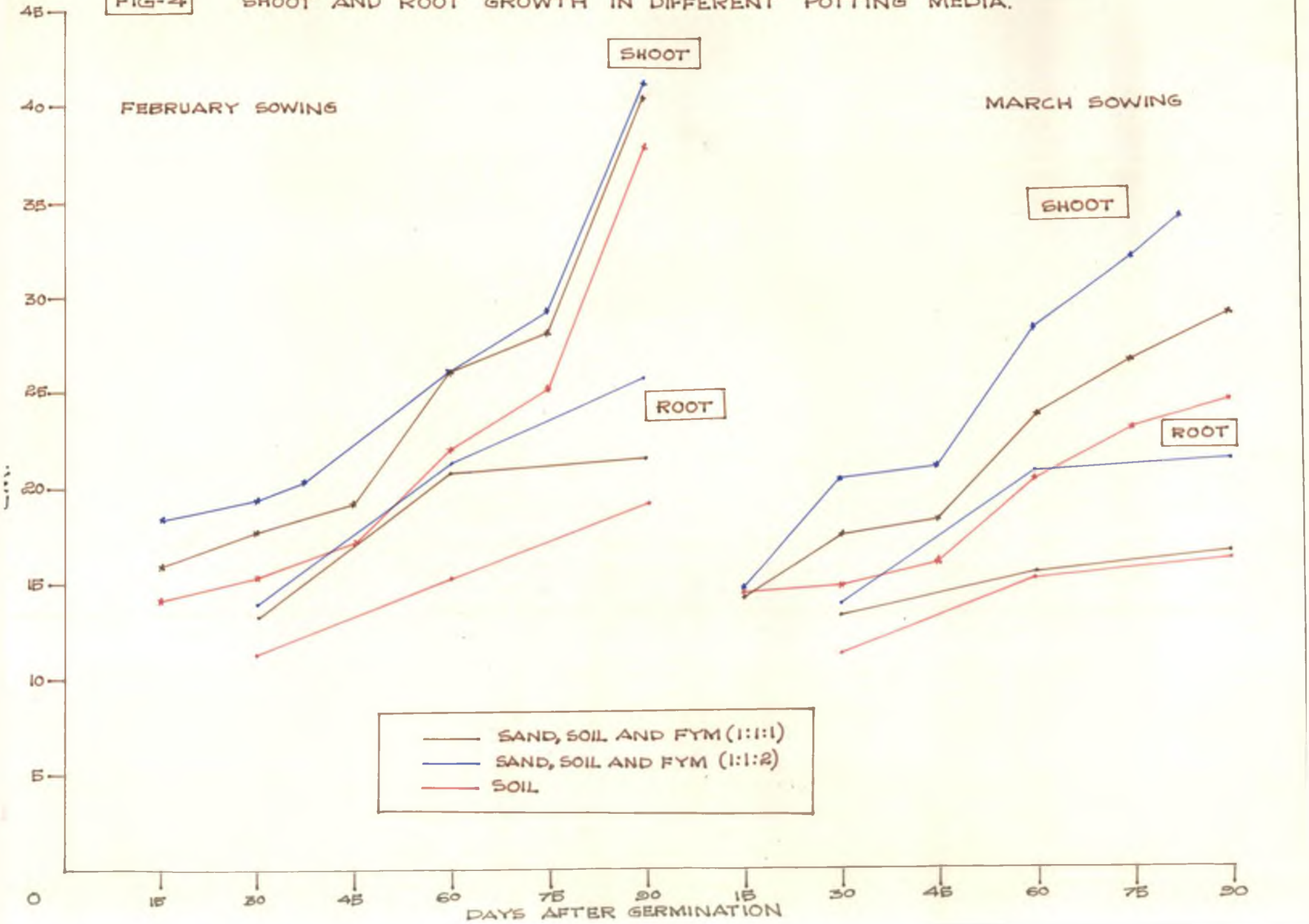
** Significant at 1% level.

Table 21c. Continued.

Days after germination.	60th day			75th day			90th day		
Treatments.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.	Height (cm)	Girth (cm)	No.of leaves.
T_1 (1:1:1)	23.70	1.56	9.30	26.42	1.88	10.80	29.00	1.90	12.00
T_2 (1:1:2)	29.20	1.84	11.00	32.02	1.90	13.00	34.04	1.96	14.40
T_3 (Soil)	20.40	1.50	8.00	22.94	1.68	10.00	24.66	1.86	10.40
F-Value	2.06^{NS}	1.40^{NS}	3.76^{NS}	3.26^{NS}	1.09^{NS}	2.30^{NS}	2.48^{NS}	0.53^{NS}	3.35^{NS}
CD(0.05)	8.48	0.47	2.66	7.01	0.35	3.15	9.10	0.21	3.30

NS Not significant

FIG-4 SHOOT AND ROOT GROWTH IN DIFFERENT POTTING MEDIA.



maximum and 15.3 cm obtained for T_3 was the minimum. The maximum height was 41.24 cm in case of T_2 with soil sand and FYM in the proportion of 1:1:2.

c) March sowing.

The height obtained for T_2 was the highest at all the intervals. Significant variation at 1 per cent level between the treatments was obtained only on the 30th day when T_2 was significantly superior to T_1 and T_3. The maximum height was 20.5 cm for T_2 and the minimum 14.18 cm for T_3. On the 90th day 34.04 cm height was recorded in T_2 and it was only 24.66 cm in T_3 and 29 cm in case of T_1.

Thus in all the three sowings the maximum height has been observed in seedlings grown in soil, sand and dried farm yard manure in the ratio of 1:1:2.

(ii) Girth.

a) December sowing.

The seedlings under T_2 (1:1:2 mixture) showed the maximum girth at all intervals. Significant variation at 5 per cent level was obtained on the 60th day. T_2 was significantly superior to T_3 (soil) and was on a par with T_1 (1:1:1). The maximum girth was 2.14 cm for T_2 and the minimum 1.76 cm for T_3.

b) February sowing.

Though no significant variation between treatments was obtained, the girth was found maximum for the seedlings in T_2(1:1:2) and minimum for those in T_3 (soil).

c) March sowing.

Here also no significant variation between the treatments was found. But T_2 had the maximum girth and T_3 the minimum.

The results conclusively proove that the seedlings grown in 1:1:2 potting mixture had the maximum girth.

(iii) Number of leaves.

a) December sowing.

The number of leaves produced were highest for T_2 (1:1:2) at all the intervals and the lowest for T_3 (soil). Significant variation at 1 per cent level was obtained on 60th day. The mean number of leaves produced for T_2 was 9.8 which was significantly superior to T_1 (7.2) and T_3(7). T_1 and T_3 were on a par.

b) February sowing.

The highest number of leaves were produced for T_2 and the lowest for T_3. No significant variation was however obtained.

c) March sowing.

The number of leeves was highest for T_2 and lowest for T_3 at all the intervals, though there was no significant difference.

From the results obtained it is quite evident that the height, girth and the number of leaves produced were higher for the seed sown in the potting mixture of soil, sand and dried farm yard manure in the ratio of 1:1:2.

Among the different months of sowing February recorded the maximum growth by height (41.24 cm) girth(2.24) cm and number of leaves(14.6)when the seedlings are 90 days old.

1.6.2 Root characters.

The mean values of the length of the tap root, the length of the longest lateral root and the number of lateral roots are presented in Table 22 a to c.

(i) Length of the tap root.

a) December sowing.

The length was greatest for T_2 (1:1:2) and shortest for T_3 (soil) on the 30th, 60th and 90th day. There was no significant variation between the treatments.

b) February sowing.

T_2 produced the maximum length and T_3 the minimum at all the intervals. There was no significant variation at any of the intervals.

c) March sowing.

The longest tap roots were produced in T_2 (1:1:2) and the shortest in T_3 (soil). However there was no significant variation.

(ii) Length of the longest lateral root.

a) December sowing.

The longest lateral roots were produced for T_2 (1:1:2) and the shortest for T_3(soil). There was no significant

Table 22a. Root growth parameters of cocoa seedlings grown in different media. December sowing.

Days after germination	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral root
T_1 (1:1:1)	13.34	2.98	23.00	15.72	6.06	51.00	16.10	8.36	56.00
T_2 (1:1:2)	13.20	3.48	25.80	16.36	6.58	64.00	24.12	11.08	81.00
T_3 (Soil)	10.70	2.76	20.00	12.78	5.42	49.00	15.72	6.08	54.00
F-Value	1.43^{NS}	1.44^{NS}	3.30^{NS}	2.71^{NS}	0.54^{NS}	1.03^{NS}	3.40^{NS}	1.15^{NS}	3.66*
CD(0.05)	4.26	0.94	4.91	3.57	2.42	24.71	7.92	7.17	24.23

NS Not significant.

Table 22b. Root growth parameters of cocoa seedlings grown in different media. February sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.
T_1 (1:1:1)	13.38	2.93	23.00	20.96	6.64	40.00	21.62	12.96	53.00
T_2 (1:1:2)	13.84	3.48	25.80	21.24	9.56	41.00	25.72	13.80	53.00
T_3 (Soil)	11.28	2.76	20.00	15.18	6.56	37.00	19.30	7.46	50.00
F-Value	1.39^{NS}	1.49^{NS}	3.39^{NS}	2.60^{NS}	1.45^{NS}	0.19^{NS}	1.31^{NS}	16.03**	0.32^{NS}
CD(0.05)	3.56	0.93	4.85	6.53	4.37	14.61	6.73	2.67	9.41

NS Not significant

** Significant at 1% level.

Table 22c. Root growth parameters of cocoa seedlings grown in different media. March sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No.of lateral roots.	Length of tap root. (cm)	Length of longest lateral root. (cm)	No. of lateral root
T_1 (1:1:1)	13.38	2.98	23.00	15.10	5.80	37.00	16.5	6.24	37.00
T_2 (1:1:2)	13.88	3.48	25.80	20.76	7.44	44.00	21.28	8.00	52.00
T_3 (Soil)	11.22	2.76	20.00	14.38	5.12	30.00	16.4	5.12	37.00
F-Value	1.59^{NS}	1.66^{NS}	4.91*	2.15^{NS}	1.03^{NS}	5.34*	4.09*	1.34^{NS}	3.02^{N}
CD(0.05)	3.45	0.88	4.03	6.99	3.61	9.32	4.26	3.85	15.35

NS Not significant
* Significant at 5% level.

difference between the treatments either on 30th, 60th or 90th day.

b) February sowing.

The seedlings in T_2 had the longest lateral roots and the shortest in T_3. Significant difference between the treatment at 1 per cent level was obtained on 90th day. The length of 13.88 cm obtained for T_2 was on par with T_1 (12.96 cm) and significantly superior to T_3(7.46 cm).

c) March sowing.

The longest lateral roots were produced in T_2(1:1:2) and the shortest in T_3(soil). No significant variation between treatments was observed.

(iii) Number of lateral roots.

a) December sowing.

The number of lateral roots were highest in T_2 and lowest in T_3. No significant difference between treatments was however noted.

b) February sowing.

In this sowing also the largest number of lateral roots were seen in T_2(1:1:2) and the smallest number in T_3 (soil). No significant difference between treatments was noted.

c) March sowing.

Significant variation between treatment was obtained on the 30th and 60th days. On the 30th day, T_2 (25.0) was significantly higher than T_3(20) and was on par with T_1(23).

T_1 and T_3 were also on a par. On the 60th day again, T_2 (44) was significantly higher than T_3(30) and was on a par with T_1(37). T_1 and T_3 were also on par.

From the results it can be seen that the length of the tap root, number of laterals and the length of the longest laterals were highest in case of T_2 and closely followed by T_1 (1:1:1). The least growth was recorded in T_3 (in soil). Among the months of sowing February sowing recorded the maximum length of tap root (25.72 cm) and laterals (13.88 cm). But the maximum number of laterals were observed in December (81) when the seedlings were 90 days old.

1.6.3 Dry weight.

The mean dry weight of the shoot, root and the total dry weight of cocoa seedlings grown in the three potting mixtures are presented in Tables 23a to c.

(i) Dry weight of shoot.

a) December sowing.

The dry weight of the shoot was highest in T_2(1:1:2) and lowest in T_3 (soil). Significant difference between treatments was obtained on the 60th day. T_2(1334 mg) was significantly superior to T_1 (1090 mg).

b) February sowing.

The highest dry weight were obtained for T_2 and the lowest for T_3. No significant variation between treatments was however obtained.

Table 23a. Dry weight of cocoa seedlings grown in different media. December sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
T_1 (1:1:1)	724	235	959	1090	249	1339	2750	380	3130
T_2 (1:1:2)	892	243	1135	1334	304	1638	2900	578	3478
T_3 (Soil)	714	171	885	1056	248	1304	2080	362	2442
F-Value	1.58^{NS}	2.04^{NS}	2.24^{NS}	5.03 *	0.48^{NS}	5.43*	0.91^{NS}	2.09^{NS}	1.14^{NS}
CD(0.05)	244.95	84.95	264.03	208.33	141.08	236.65	1409.58	259.83	1517.

NS Not Significant

* Significant at 5% level.

Table 23b. Dry weight of cocoa seedlings grown in different media. February sowing.

Days after germination.	30th day			60th day			90th day		
Treatments.	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
T_1 (1:1:1)	710	240	950	1770	390	2160	2016	434	2450
T_2 (1:1:2)	863	246	1109	2120	432	2552	2130	658	2796
T_3 (Soil)	707	180	887	1580	330	1910	1836	390	2226
F-Value	1.78^{NS}	1.74^{NS}	3.29 ^{NS}	1.26^{NS}	1.01^{NS}	1.70^{NS}	0.61^{NS}	3.91^{NS}	2.44^{NS}
CD(0.05)	205.97	85.06	232.77	749.98	157.06	763.84	595.67	223.84	566.29

NS Not significant.

Table 23c. Dry weight of cocoa seedlings grown in different media. March sowing.

Days after germination.									
Treatments.	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)	Shoot (mg)	Root (mg)	Total (mg)
T_1 (1:1:1)	724	222	946	1204	240	1444	2132	325	2457
T_2 (1:1:2)	902	246	1148	1779	334	2113	2566	372	2938
T_3 (Soil)	716	168	884	1055	208	1263	2110	246	2356
F-Value	1.46^{NS}	2.72^{NS}	1.95^{NS}	3.96^{*}	2.16^{NS}	3.90^{*}	0.51^{NS}	2.22^{NS}	0.74^{NS}
CD(0.05)	268.03	74.51	304.15	591.9	137.00	698.26	1103.97	131.46	1109.

NS Not significant

* Significant at 5% level.

c) March sowing.

The highest dry weights were obtained for T_2(1:1:2) and the lowest for T_3(soil). Significant difference between treatments was obtained at the 60th day when T_2 (1779 mg) was significantly superior to T_3 (1055 mg) and was on a par with T_1 (1204 mg). T_1 and T_3 were also on par.

(ii) Dry weight of root.

a) December sowing.

The dry weight of the roots was highest for T_2 (1:1:2) and lowest for T_3 (soil). No significant variation between treatments was obtained.

b) February sowing.

Though no significant variation between treatments was noted, the roots in T_2 had the highest and those in T_3 the lowest dry weights.

c) March sowing.

The dry weight was highest in T_2 and lowest in T_3. No significant variation was however, obtained.

(iii) Total dry weight.

a) December sowing.

At all the intervals, the total dry weight was highest for T_2 (1:1:2) and lowest for T_3 (soil). Significant difference between the treatments at 5 per cent level was obtained on 60th day. T_2 (1639 mg) was significantly superior to T_1(1339 mg) and T_3 (1304 mg) which were on par.

b) February sowing.

The total dry weight was highest for T_2 (1:1:2) and lowest for T_3(soil). There was no significant difference either on 30th, 60th or 90th day.

c) March sowing.

The total dry weight was highest for T_2 and lowest for T_3. Significant variation between treatments at 5 per cent level was obtained on 60th day. T_2(2113 mg) was significantly superior to T_3 (1263 mg) and was on par with T_1 (1444 mg). T_1 and T_3 were also on par.

Thus it can be seen from the results that the dry weight of the shoot and the root and the total dry weight were higher in case of the 1:1:2 medium and lowest in the soil medium. Among the different periods the total dry weight (3478 mg) and the dry weight of shoot (2900 mg) were higher in December sowing while the dry weight of the roots was maximum (658 mg) in February sowing.

1.7 Viability of Seeds in Storage

The data on the percentage of germination for the various treatments are presented in Table 24.

Pods kept as such in the room conditions showed the maximum germination. After three days the germination percentage was 78.02 and after 12 days 23.33 per cent. The seeds extracted and kept at room temperature, showed germination upto the 6th day of storage though the percentage

Table 24. Germination of cocoa seeds under various conditions of storage (Mean percentage)

Days after harvest.	Room temperature		Refrigerated conditions	
	In the pod	Extracted	In the pod	Extracted
3	78.02	44.44	Nil	Nil
6	66.29	20.00	Nil	Nil
9	30.89	Nil	Nil	Nil
12	23.33	Nil	Nil	Nil

was very low (20) . The pods and the seeds kept under refrigerated conditions did not show any germination even on the 3rd day.

1.8 Root Growth Studies

The data on the root characters studied are presented in Table 25 and the different stages of root growth in Plate VII and VIII.

The root characters of 15,30,60,90, 180 and 270 day old, seedlings were studied. The mean length of the tap root was 13.12 cm when the seedlings were 15 day old and 29.93 cm when 9 months old. The mean length of the longest lateral of 15 day old seedlings was 2.78 cm and that of 270 day old seedlings 29.93 cm. The mean numbers of lateral roots of 15 days and 270 days old seedlings were 34.5 and 78.0 respectively. The mean dry weight of the root was 161mg when the seedlings were 15 days old and 4.69 g when 270 days old. The same is presented graphically in Figure 5.

Thus from the Table it can be seen that the growth of the tap root and the laterals was at a faster rate upto 15 days by which time the tap root grew 43.8 per cent of the growth upto 270 days and the number of laterals was 44.2 per cent. By the time the seedlings are 30 days old, 57.2 per cent growth of the tap root was completed and the number of laterals increased upto 70.7 per cent. The rate of tap root growth and the production of laterals were comparatively

Table 25. Root growth of cocoa seedlings at various intervals. (Mean of 20 seedlings)

Age of seedlings	Length of tap root (cm)	Percentage of increase in tap root growth	Length of longest lateral root (cm)	Percentage of increase in length of longest lateral root	No.of lateral roots	Percentage of increase in number of lateral roots	Dry weight of root (mg)	Percentage increase in dry weight of root	Dry weight of shoot (mg)	Percentage increase in dry weight of shoot
15 days	13.12	43.80	2.78	15.20	34.50	44.20	161.00	3.40	359.30	3.21
30 days	17.11	13.30	3.18	2.20	55.15	26.50	161.25	0.01	655.50	2.64
60 days	18.05	3.10	3.64	2.50	61.80	8.50	352.00	4.10	1730.00	9.59
90 days	18.37	1.10	8.18	24.80	62.15	0.50	636.00	6.10	2720.00	8.84
180 days	23.45	17.00	16.94	47.90	71.75	12.30	3314.50	57.09	10350.00	68.13
270 days	29.93	21.70	18.29	7.40	78.00	8.00	4688.00	29.30	11200.00	7.59

Note: The percentage increase is based on the values for the 270th day

PLATE VII Different stages of root growth.

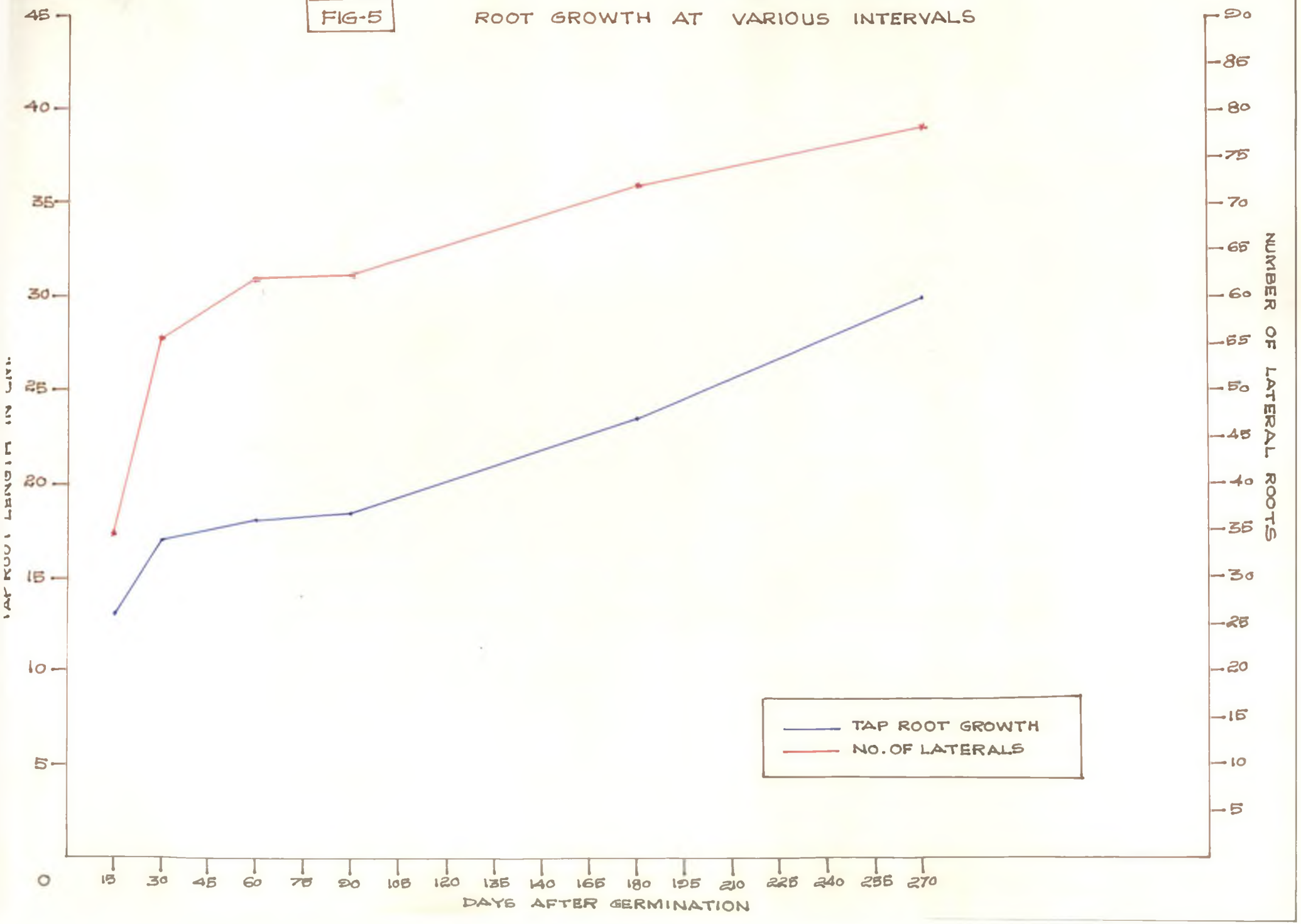

90


150

PLATE VIII Root growth of seedlings showing coiling of roots.

FIG-5

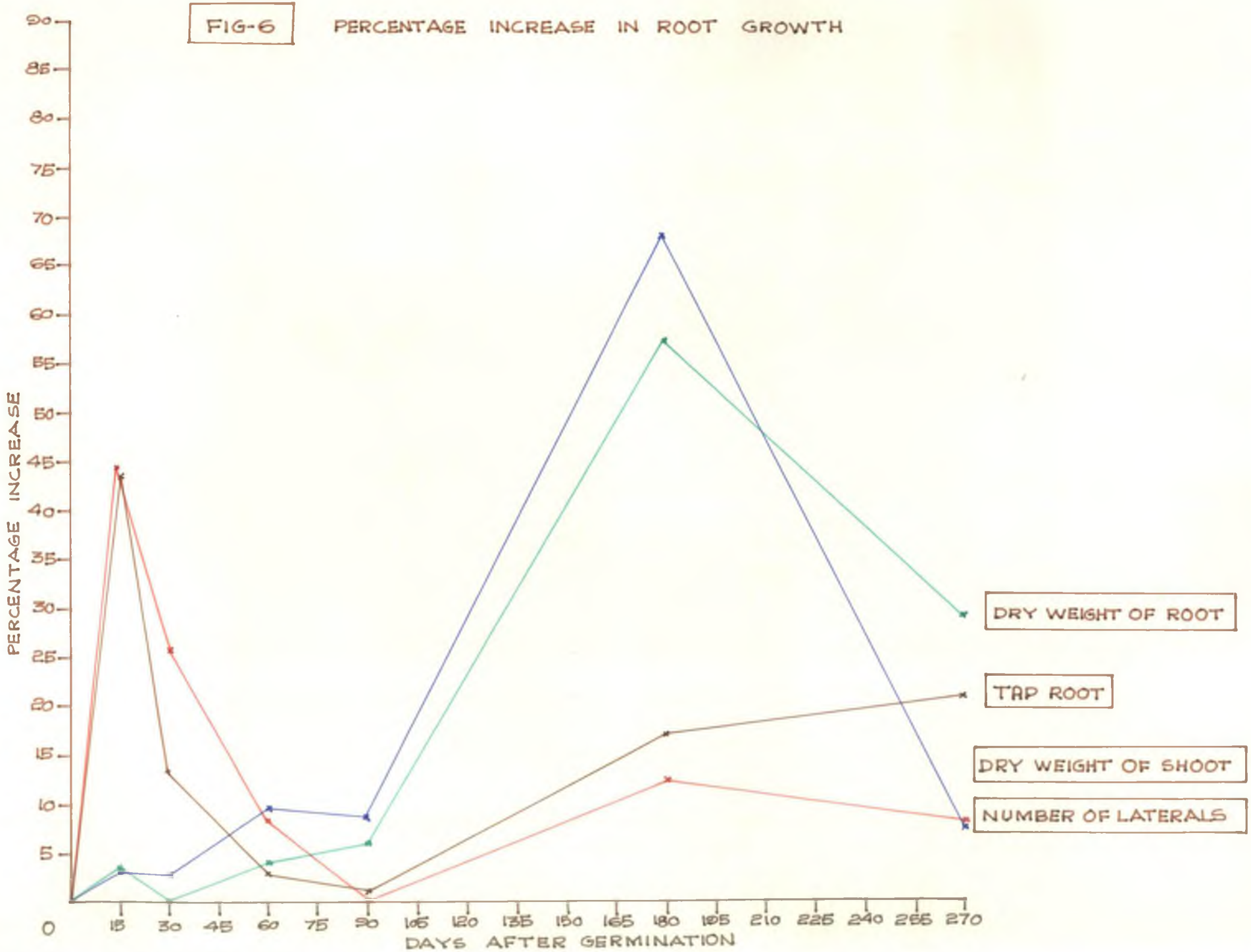
ROOT GROWTH AT VARIOUS INTERVALS



slow during the period between 30 and 90 days of growth, thereafter it gradually increased upto 90 days. But the rate of increase in growth was faster between 90 and 180 days thane from 180 to 270 days. The same is presented in Figure 6.

Figure 6 also makes clear that the increase in the growth rate and the increase in dry weight of the shoot and root were alternated. In other words when the percentage of increase of tap root and number of laterals were higher, the percentage of accumulation of dry matter was less and vice versa. The accumulation of dry matter was more in shoots than in roots and the percentage of increase in dry matter accumulation was also more in shoots till 180 days after germination. Thereafter the dry matter accumulation was at a faster rate in roots than in shoots upto 270 days. Since the root growth from 90 to 120 days is quite low it will be advisable that the plants are transplanted during this period for better establishment. The length of tap root and the number of lateral roots are also not too large during this time so that it can be easily accommodated without coiling in a polythene bag of 30 x 20 cm.

FIG-6 PERCENTAGE INCREASE IN ROOT GROWTH



2. VEGETATIVE PROPAGATION

2.1 Rooting of Cuttings

The data on the percentage of rooting, average number of roots and the average length of the roots, 60 days after potting in the nursery are presented in Table 26a and 26b.

2.1.1 Mist chamber method.

(i) Percentage of rooting.

Statistical analysis showed that there was significant variation at 1 per cent level in the percentage of rooting. The percentage of rooting was significantly higher for T_{12} (96.3) followed by T_{24}(94.9), T_1(84.3), T_{15}(81.6), T_{14}(80), T_{13} and T_{11}(70.8). The lowest percentage of rooting was obtained for T_{60} (1.1) which was lower than the control(3.7).

(ii) Number of roots.

Statistical analysis showed significant variation at 1 per cent level. The mean number of roots was significantly higher for T_{25}(10.76) followed by T_{26}(9.63) and T_{30}(7.64). The number of roots was lowest in T_{55}(0.28) and T_{60}(0.30). The number of roots obtained for control was 0.30 .

(iii) Length of roots.

The mean length of the roots was maximum for T_2(5.7cm) followed by T_3(5.35 cm), T_1(5.34 cm), T_9(5.06 cm) and T_{27} (4.25 cm).

Table 26a. Rooting data of cocoa semi-hardwood cuttings treated with different plant growth regulators. Mist chamber method.

	Treatments	Percentage of rooting@	Mean number of roots@@	Mean length of roots(cm)@@@
1	IAA 2000 ppm 10 sec	84.3 (66.63)	2.42 (1.85)	5.34
2	IAA 2000 ppm 20 sec	56.6 (37.23)	2.31 (1.82)	5.7
3	IAA 2000 ppm 30 sec	50.1 (45.08)	4.57 (2.36)	5.35
4	IAA 2000 ppm 60 sec	36.6 (37.22)	3.49 (2.12)	3.33
5	IAA 4000 ppm 10 sec	29.2 (32.70)	6.78 (2.79)	3.53
6	IAA 4000 ppm 20 sec	60.6 (51.14)	2.09 (1.76)	3.60
7	IAA 4000 ppm 30 sec	60.6 (51.14)	4.43 (2.34)	2.60
8	IAA 4000 ppm 60 sec	33.3 (35.21)	4.19 (2.28)	2.28
9	IAA 6000 ppm 10 sec	63.4 (52.77)	4.38 (2.32)	5.06
10	IAA 6000 ppm 20 sec	56.8 (48.93)	3.84 (2.20)	4.21
11	IAA 6000 ppm 30 sec	70.8 (57.29)	4.80 (2.41)	3.72
12	IAA 6000 ppm 60 sec	96.3 (78.93)	4.06 (2.25)	3.37
13	IAA 8000 ppm 10 sec	70.8 (57.29)	3.50 (2.14)	2.31
14	IAA 8000 ppm 20 sec	80.0 (63.44)	5.30 (2.51)	1.93
15	IAA 8000 ppm 30 sec	81.6 (64.63)	5.81 (2.61)	2.17
16	IAA 8000 ppm 60 sec	66.7 (54.78)	6.13 (2.67)	3.15
17	NAA 2000 ppm 10 sec	56.7 (48.84)	2.53 (1.88)	3.10
18	NAA 2000 ppm 20 sec	50.5 (45.29)	4.96 (2.42)	3.21
19	NAA 2000 ppm 30 sec	39.7 (39.06)	3.00 (2.00)	3.20
20	NAA 2000 ppm 60 sec	43.3 (41.15)	4.48 (2.34)	2.19
21	NAA 4000 ppm 10 sec	36.4 (37.14)	4.90 (2.43)	3.41
22	NAA 4000 ppm 20 sec	30.0 (33.21)	5.00 (2.45)	2.21
23	NAA 4000 ppm 30 sec	50.0 (45.00)	3.62 (2.15)	2.04
24	NAA 6000 ppm 60 sec	94.9 (76.92)	5.71 (2.59)	2.92

Table 26a. Continued.

	Treatments	Percentage of rooting	Mean number of roots	Mean length of roots(cm)
25	NAA 6000 ppm 10 sec	46.0(42.70)	10.76(3.43)	2.05
26	NAA 6000 ppm 20 sec	39.3(38.85)	9.63(3.26)	2.66
27	NAA 6000 ppm 30 sec	23.2(28.77)	3.04(2.01)	4.25
28	NAA 6000 ppm 60 sec	39.3(38.85)	2.61(1.90)	1.84
29	NAA 8000 ppm 10 sec	53.3(46.92)	2.30(1.95)	2.54
30	NAA 8000 ppm 20 sec	26.5(30.99)	7.34(2.94)	2.25
31	NAA 8000 ppm 30 sec	43.3(41.15)	3.12(2.03)	2.74
32	NAA 8000 ppm 60 sec	30.0(33.21)	3.04(2.01)	2.50
33	IBA 2000 ppm 10 sec	36.4(37.14)	2.03(1.74)	1.99
34	IBA 2000 ppm 20 sec	53.3(46.92)	4.90(2.43)	2.48
35	IBA 2000 ppm 30 sec	66.7(54.78)	4.76(2.40)	3.40
36	IBA 2000 ppm 60 sec	43.2(41.07)	6.02(2.65)	1.78
37	IBA 4000 ppm 10 sec	39.7(39.06)	2.28(1.81)	1.51
38	IBA 4000 ppm 20 sec	30.0(33.21)	5.00(2.57)	2.17
39	IBA 4000 ppm 30 sec	43.2(41.07)	5.10(2.47)	2.46
40	IBA 4000 ppm 60 sec	56.8(48.93)	3.49(2.12)	1.31
41	IBA 6000 ppm 10 sec	22.4(28.28)	3.12(2.03)	2.31
42	IBA 6000 ppm 20 sec	26.2(30.78)	2.46(1.86)	1.95
43	IBA 6000 ppm 30 sec	28.5(32.30)	3.54(2.13)	1.75
44	IBA 6000 ppm 60 sec	36.4(37.14)	3.04(2.01)	3.07
45	IBA 8000 ppm 10 sec	15.7(23.36)	1.31(1.53)	0.87
46	IBA 8000 ppm 20 sec	26.2(30.78)	2.35(1.83)	2.30
47	IBA 8000 ppm 30 sec	23.2(28.77)	6.40(2.72)	2.46
48	IBA 8000 ppm 60 sec	18.3(25.37)	4.02(2.24)	2.83

Table 26a. Continued.

	Treatments	Percentage of rooting	Mean number of roots	Mean length of roots(cm)
49	NAA and IBA 2000 ppm 10 sec	13.0 (21.14)	4.71(2.39)	2.40
50	NAA and IBA 2000 ppm 20 sec	26.2 (30.78)	5.71(2.59)	1.58
51	NAA and IBA 2000 ppm 30 sec	13.0 (21.14)	2.24(1.80)	1.93
52	NAA and IBA 2000 ppm 60 sec	21.0 (27.29)	1.22(1.49)	1.99
53	NAA and IBA 4000 ppm 10 sec	26.5 (30.99)	2.35(1.83)	1.67
54	NAA and IBA 4000 ppm 20 sec	26.2 (30.78)	2.13(1.77)	2.50
55	NAA and IBA 4000 ppm 30 sec	2.4 (8.85)	0.28(1.13)	0.37
56	NAA and IBA 4000 ppm 60 sec	32.9 (35.00)	1.46(1.57)	1.47
57	NAA and IBA 6000 ppm 10 sec	2.4 (8.85)	0.69(1.30)	0.50
58	NAA and IBA 6000 ppm 20 sec	10.0 (18.44)	2.13(1.77)	0.63
59	NAA and IBA 6000 ppm 30 sec	9.2 (17.70)	0.77(1.33)	1.83
60	NAA and IBA 6000 ppm 60 sec	1.1 (6.14)	0.30(1.14)	1.17
61	NAA and IBA 8000 ppm 10 sec	9.2 (17.70)	1.86(1.69)	0.71
62	NAA and IBA 8000 ppm 20 sec	10.0 (18.44	6.56(2.75)	1.59
63	NAA and IBA 8000 ppm 30 sec	5.3 (12.29)	1.22(1.49)	1.42
64	NAA and IBA 8000 ppm 60 sec	9.2 (17.70)	1.59(1.58)	0.58
	Control	3.7 (11.07)	0.30(1.14)	0.38
	F-Value	2.88**	11.03**	
	CD(0.05)	15.36	0.33	

** Significant at 1% level.
@ The values in parenthesis denote angular transformed ones.
@@ The values in parenthesis are expressed as $\sqrt{x+1}$.
@@@ Not analysed statistically as there was no rooting in certain replications which resulted in incomplete data.

Table 26b. Rooting data of cocoa semi-hardwood cuttings treated with different plant growth regulators. Polythene sheet method.

	Treatments		Percentage@ of rooting	Mean number of roots@@	Mean length of roots(cm) @@@
1	IAA 2000 ppm	10 sec	77.6 (61.71)	2.53 (1.88)	3.31
2	IAA 2000 ppm	20 sec	33.3 (35.21)	2.13 (1.77)	4.46
3	IAA 2000 ppm	30 sec	60.3 (50.93)	4.29 (2.30)	6.39
4	IAA 2000 ppm	60 sec	33.3 (35.21)	2.35 (1.83)	3.57
5	IAA 4000 ppm	10 sec	53.0 (46.71)	4.15 (2.27)	5.72
6	IAA 4000 ppm	20 sec	70.8 (57.29)	2.80 (1.95)	5.83
7	IAA 4000 ppm	30 sec	76.2 (60.78)	3.84 (2.20)	3.41
8	IAA 4000 ppm	60 sec	43.2 (41.07)	3.24 (2.06)	4.93
9	IAA 6000 ppm	10 sec	66.7 (54.78)	3.33 (2.08)	5.62
10	IAA 6000 ppm	20 sec	43.2 (41.07)	4.06 (2.25)	2.14
11	IAA 6000 ppm	30 sec	60.6 (51.14)	5.05 (2.46)	3.07
12	IAA 6000 ppm	60 sec	85.8 (67.86)	3.08 (2.02)	2.33
13	IAA 8000 ppm	10 sec	60.6 (51.14)	2.53 (1.88)	3.00
14	IAA 8000 ppm	20 sec	80.0 (63.44)	3.04 (2.01)	2.76
15	IAA 8000 ppm	30 sec	39.7 (39.06)	3.16 (2.04)	2.37
16	IAA 8000 ppm	60 sec	63.4 (52.77)	3.80 (2.19)	3.70
17	NAA 2000 ppm	10 sec	36.4 (37.14)	2.24 (1.80)	4.24
18	NAA 2000 ppm	20 sec	57.2 (49.14)	5.55 (2.56)	3.13
19	NAA 2000 ppm	30 sec	43.2 (41.07)	3.84 (2.20)	3.80
20	NAA 2000 ppm	60 sec	46.6 (43.07)	9.43 (3.23)	4.50
21	NAA 4000 ppm	10 sec	43.2 (41.07)	7.00 (2.83)	3.07
22	NAA 4000 ppm	20 sec	30.0 (33.21)	5.15 (2.48)	2.73
23	NAA 4000 ppm	30 sec	50.0 (45.00)	7.18 (2.86)	3.28
24	NAA 4000 ppm	60 sec	80.6 (63.84)	4.15 (2.27)	2.87

Table 26b. Continued.

	Treatments	Percentage of rooting	Mean number of roots	Mean length of roots(cm)
25	NAA 6000 ppm 10 sec	32.3 (34.63)	11.89(3.59)	4.94
26	NAA 6000 ppm 20 sec	29.2 (32.70)	5.30(2.51)	6.15
27	NAA 6000 ppm 30 sec	53.0 (46.71)	4.15(2.27)	3.19
28	NAA 6000 ppm 60 sec	23.2 (28.77)	6.29(2.70)	4.31
29	NAA 8000 ppm 10 sec	46.5 (43.07)	2.65(1.91)	2.28
30	NAA 8000 ppm 20 sec	15.7 (23.36)	3.00(2.00)	1.59
31	NAA 8000 ppm 30 sec	46.5 (43.07)	4.29(2.30)	2.61
32	NAA 8000 ppm 60 sec	15.7 (23.36)	3.00(2.00)	1.64
33	IBA 2000 ppm 10 sec	43.2 (41.07)	5.40(2.53)	4.51
34	IBA 2000 ppm 20 sec	39.7 (39.06)	7.53(2.92)	3.79
35	IBA 2000 ppm 30 sec	50.1 (45.08)	5.35(2.52)	2.91
36	IBA 2000 ppm 60 sec	39.8 (39.14)	6.34(2.71)	2.34
37	IBA 4000 ppm 10 sec	49.9 (44.91)	2.83(1.97)	3.34
38	IBA 4000 ppm 20 sec	30.0 (33.21)	6.40(2.72)	2.68
39	IBA 4000 ppm 30 sec	36.4 (37.14)	3.49(2.12)	4.27
40	IBA 4000 ppm 60 sec	63.5 (52.86)	5.60(2.57)	5.30
41	IBA 6000 ppm 10 sec	15.7 (23.36)	1.13(1.46)	2.13
42	IBA 6000 ppm 20 sec	32.9 (35.00)	4.76(2.40)	5.91
43	IBA 6000 ppm 30 sec	18.4 (25.37)	3.00(2.00)	4.20
44	IBA 6000 ppm 60 sec	43.2 (41.07)	2.57(1.89)	4.23
45	IBA 8000 ppm 10 sec	26.5 (30.99)	3.28(2.07)	1.57
46	IBA 8000 ppm 20 sec	32.9 (35.00)	4.48(2.34)	3.32
47	IBA 8000 ppm 30 sec	26.5 (30.99)	6.04(2.90)	2.54
48	IBA 8000 ppm 60 sec	28.6 (32.30)	6.70(2.79)	3.03

Table 26b. Continued.

Treatments	Percentage of rooting	Mean number of roots	Mean length of roots (cm)
49 NAA and IBA 2000 ppm 10 sec	16.4(23.85)	3.49 (2.12)	3.70
50 NAA and IBA 2000 ppm 20 sec	32.9(35.00)	7.00 (2.83)	3.64
51 NAA and IBA 2000 ppm 30 sec	16.4(23.03)	2.06 (1.75)	4.92
52 NAA and IBA 2000 ppm 60 sec	24.8(26.14)	3.65 (1.91)	3.63
53 NAA and IBA 4000 ppm 10 sec	23.2(28.77)	3.35 (1.83)	2.57
54 NAA and IBA 4000 ppm 20 sec	32.9(35.00)	4.02 (2.24)	3.04
55 NAA and IBA 4000 ppm 30 sec	9.3(17.70)	1.16 (1.47)	2.82
56 NAA and IBA 4000 ppm 60 sec	26.2(30.73)	6.24 (2.69)	6.16
57 NAA and IBA 6000 ppm 10 sec	9.3(17.70)	1.28 (1.51)	2.12
58 NAA and IBA 6000 ppm 20 sec	10.0(18.44)	2.72 (1.93)	1.57
59 NAA and IBA 6000 ppm 30 sec	2.4(8.85)	0.42 (1.19)	1.03
60 NAA and IBA 6000 ppm 60 sec	0.0(@)	0.0 (1.00	0.00
61 NAA and IBA 8000 ppm 10 sec	2.4(8.85)	0.28 (1.13)	0.47
62 NAA and IBA 8000 ppm 20 sec	10.0(18.44)	0.99 (1.41)	2.00
63 NAA and IBA 8000 ppm 30 sec	1.15(6.14)	1.25 (1.45)	0.30
64 NAA and IBA 8000 ppm 60 sec	2.4 (8.85)	0.61 (1.27)	0.33
Control	8.8 (17.22)	1.34 (1.53)	0.71
F-Value	2.39**	6.04**	
CD(0.05)	16.25	0.40	

** Significant at 1% level.

@ The values in parenthesis denote angular transformed ones.
@@ The values in parenthesis are expressed as $\sqrt{x+1}$.
@@@Not analysed statistically as there was no rooting in certain replications which resulted in incomplete data.

2.1.2 Polythene sheet method.

(i) Percentage of rooting.

Statistical analysis showed significant variation at 1 per cent level. The percentage of rooting was significantly higher for T_{12}(85.8) followed by T_{24}(80.6) and T_{14}(80). The percentage of germination was lowest for T_{60} where there was no rooting. The control showed 8.8 per cent rooting.

(ii) Number of roots.

Statistical analysis showed significant difference at 1 per cent level. The mean number of roots was highest for T_{25} (11.89) followed by T_{20} (9.43), T_{23}(7.18), T_{21} and T_{50} (7.00), T_{47} (6.84) and T_{48} (6.78).

(iii) Length of roots.

The average length of the roots was highest in T_3 (6.39 cm) followed by T_{56}(6.16 cm) and T_{26} (6.15 cm). The lowest average length was recorded for T_{63}(0.30 cm) and T_{64}(0.33). The control recorded 0.71 cm.

Among the two methods i.e. the 'mist chamber' and the 'polythene sheet' method, the highest percentage was obtained with the mist chamber method. The rooting percentage was 11 per cent more. However the average number of roots (11.89) was highest in the 'polythene sheet' method compared to the 'mist chamber' method (10.76). Similarly the average length of the root was also more in 'polythene sheet'

method (6.5) than the 'mist chamber' method (5.7). However, both methods can be adopted under our conditions depending upon the situations. In the case of the polythene sheet method the percentage will be slightly low; but the number of roots per cuttings will be higher. The question of survival of the rooted cuttings have to be ascertained before suggesting a single method.

Among the treatments it was found that IAA at 6000 ppm concentration treated for 60 sec gave the maximum percentage rooting of 96.9. In certain replications the percentage of rooting was even 100 per cent for this treatment. NAA at 4000 ppm treated for 60 sec gave 94.9 per cent rooting with 100 per cent in certain replications.

However, when the number of roots and the average length of roots were also taken into account NAA at 4000 ppm treated for 60 sec is slightly superior. Therefore IAA at 6000 ppm or NAA at 4000 ppm for 60 sec are suggested for rooting of cocoa cuttings (Plate IX). IBA, though in general is more effective for rooting, is not found producing the effect in this case. Though synergetic effect is expected by the combination of NAA and IBA the same was not found very effective in the present investigation.

PLATE IX Rooted cuttings.


70
65
60
55
CONTEN


NAA
4000

2.2 Budding

The results of the four methods of budding carried out are presented in Table 27. The 'T','inverted-T', patch and forkert methods of budding were carried out on 7 to 11 months old root stocks from January to May 1979.

In January the percentage of success was 35 for the 'T' and 'inverted-T' methods and 30 for patch budding while the forkert method gave 50 per cent success.

In February the percentage of success increased to 40 and 45 for the 'T' and 'inverted-T' methods respectively and 35 for patch budding. The forkert method gave 60 per cent success.

In March 45 per cent success was obtained for the 'T' and 'inverted-T' methods while for patch and forkert the corresponding percentage of success were 40 and 60 respectively.

In April 35 per cent success was obtained for 'T' and patch budding while for the 'inverted-T' method it was 30 per cent. The forkert method gave 55 per cent success.

Thus among the four methods of budding carried out, the forkert method gave the maximum success while the 'inverted-T' and patch methods ranged next. The maximum success was obtained in February and March when the budding was done on eight and nine months old root stocks. Plate X shows a budded plant.

Table 27. Budding of cocoa seedlings.

MONTHS	JANUARY			FEBRUARY			MARCH			APRIL			MAY		
AGE OF S.S	7			8			9			10			11		
Treatments.	Number budded	Number of take	Percentage of success.	Number budded	Number of take	Percentage of success.	Number budded	Number of take	Percentage of success.	Number budded	Number of take	Percentage of success.	Number budded	Number of take	Percentage of success
'T' budding.	20	7	35	20	8	40	20	9	45	20	7	35	20	7	35
Inverted 'T'	20	7	35	20	9	45	20	9	45	20	6	30	20	7	35
Patch	20	6	30	20	7	35	20	8	40	20	7	35	20	8	40
Forkert	20	12	50	20	12	60	20	12	60	20	10	50	20	11	55

PLATE X Budded plant two months after budding.

2.3 Green Budding

The data on green budding is presented in Table 28. The percentage of success was 40 in all the methods for two months old root stock using green buds. But when the buds were taken from greenish brown coloured twings, the percentage of success was 60 in case of forkert method, while it was only 40% in other methods.

On three month old root stocks use of green buds gave 40 per cent success for 'T' and 'inverted-T' methods, 20 per cent for patch and 60 per cent for forkert. Using buds from greenish brown coloured twings, 100 per cent success was obtained in the forkert method and 80 per cent in the 'inverted-T' method. But the success was only 40 per cent for 'T' and patch budding.

When four months old root stocks were used 20 per cent success was obtained in all the methods using green buds The success was 40 per cent for 'T' and patch budding and 80 per cent for the inverted-T and the forkert methods when the buds were taken from greenish brown coloured twigs.

The data, therefore indicates that 100 per cent

Table 28. Green budding of cocoa seedlings.

MONTHS	MARCH			APRIL			MAY		
AGE OF R.S	2			3			4		
Treatments	Number budded	Number of take	Percentage of success	Number budded	Number of take	Percentage of success	Number budded	Number of take	Percentage of success
'T'budding									
Green	5	2	40	5	2	40	5	1	20
Greenish brown	5	2	40	5	2	40	5	2	40
Inverted'T'									
Green	5	2	40	5	2	40	5	1	20
Greenish brown	5	2	40	5	4	80	5	4	80
Patch									
Green	5	2	40	5	1	20	5	1	20
Greenish brown	5	2	40	5	2	40	5	2	40
Forkert									
Green	5	2	40	5	3	60	5	1	20
Greenish brown	5	3	60	5	5	100	5	4	80

success can be obtained by the forkert method when three to four months old root stocks are used for budding during the months of March and April with the buds taken from the twigs which are greenish brown in colour. Buds taken from green twigs are found to be less successful. 60 per cent success can be obtained by the forkert method even when the root stocks are two months old.

DISCUSSION

DISCUSSION

In view of the popularisation of large scale cultivation of cocoa in Kerala it has been necessitated to standardise the production of quality seedlings and also the vegetative propagation methods in order to obtain quality, high yielding progenies. Therefore, a study on the above aspects was made and the results of the present investigations on the various aspects of quality seedling production and vegetative propagation methods are discussed below.

1. SEED PROPAGATION

1.1 Pod characters, Seed characters and Germination

The result of the present investigation indicated that the volume and weight of the pod varied among the classes of pods (large, medium and small) and also within each class in the different months. The pods harvested in December and February had comparatively higher volume while the pods harvested in December and April recorded the highest weight in all the classes. The volume and weight were highest for large pods which is quite natural because of its size. The variation in volume and weight in the different months may be due to the climatic and the environmental factors prevalent during the critical period of growth of the pods.

There was not much variation in the number of seeds among the three classes; but variation was noticed in the number of seeds produced in the different months with maximum in February followed by March and April.

The average weight of the seed has highest for large pods and lowest for small pods. The average weight of the seed was also found to be highest in February followed by March and April. The fact that there was not much variation in the number of seeds produced in the different classes indicated that the pods of any size can be utilized for seed purposes; but the fact that the average weight of the seed was lowest in small pods indicates that the small pods may be avoided to produce more vigorous seedlings. In general, number of seeds and the mean weight of sound seeds were higher during February to April suggesting that the pods harvested during these months will be more desirable for raising the nursery.

The germination studies indicated clearly that neither the size of the pod nor the position of the seed within the pod (pedicel end, middle and distal end) had any influence on the germination percentage. Hence, pods of any size and all sound seeds in a pod can be selected, if germination alone is taken into consideration.

Among the different months, without considering the classes of pods and the position of seeds in the pods, the germination percentage was highest for March sowing (94.5)

followed by February (85.58) January (79.29), December (78.44) and April (77.46). This indicates that the pods harvested in February and March will be better for obtaining higher germination than the pods harvested in December, January or April. More number of seedlings can also be expected from the pods harvested in February and March as the number of seeds and the mean weight per seed are found to be more in the pods harvested during these months. Therefore, the study indicates that for better germination and for more number of seedlings, the pods harvested in February and March will be desirable. This season will be suitable for raising the nursery for planting three to five month old seedlings from the middle of May to the end of June which will be the best period for planting cocoa under Kerala conditions.

The data on the above factors suggested that large and medium sized pods collected in February and March will be most suitable for producing more number of seedlings and also to produce the optimum aged plants for planting in May and June.

1.2 Vegetative Growth

During the December sowing significant difference in the height was observed on the 15th, 30th, 45th and 60th day after germination. The girth varied significantly only on the 60th day after germination while the number of leaves differed significantly on the 45th and60th day. There was no significant difference in height, girth and the number of

leaves on the 90th day after germination when the size of the pods as well as the position of seeds within the pod were taken into consideration.

In general there was no correlation between the height of the plant at 15 days after germination and different fruit characters such as length, girth, volume and weight of the pods. There was also no correlation between the volume and weight of the pods and number of sound seeds recorded per pod. However in February and March in the case of large pods, the girth and the weight of the pod were found to be positively correlated with the height of the plant on 90th day. In the case of pods harvested in March, under 'large' size, the volume and weight of the pod was found to be positively correlated with the height of the plant on 90th day. In the case of 'medium' sized pods harvested in April, the girth and volume was found to be negatively correlated with the height of the plant on 90th day. Therefore the results indicate no general correlation between the pod and seed characters and the height of the seedlings on 15th and 90th day.

The seeds extracted from small pods produced shorter seedlings (28.1 cm) while the height of seedlings was 33.48 cm in the case of large pods and 30.24 cm in case of medium pods. Although no significant differences in the height, girth and number of leaves produced were observed on the 90th day, the readings were higher for large and medium size pods

indicating the suitability of such pods for the production of seedlings than the small pods. The height, girth and number of leaves produced on the 90th day were 33.48cm, 2.16 cm and 12.02 cm respectively for large pods and 30.24 cm, 2.04 cm and 11.27 cm respectively for medium pods.

Summing up, the growth parameters such as the height, the girth and the number of leaves per plant are not found to vary significantly when the seeds are separated on the basis of pod size and position of seed within the pod. Though significant difference in height was observed on the 15th to 60th day after germination the difference was not significant thereafter. Such variations were also found in other characters. However, it is pertinent to point out that on the 90th day after germination there was no significant difference in any of the characters studied including the root characters. The differences in these characters, when taking into account of the position within a particular class of pod, was not found to vary much in all the five months of sowing indicating thereby that the position of seeds within a fruit is not important in the production of quality seedlings.

1.3 Root Growth

The number of lateral roots of the seedlings obtained from different sizes of pods varied significantly on the 60th day, the number being significantly higher for 'large' (76.66) and it was on par with 'medium' (75.55). However,

there was no significant difference on the 75th day. On the 90th day, the number of lateral roots again differed significantly with maximum in 'medium' (124.80) which was on par with that of 'large' (122.44).

Although no significant difference was noticed in the dry weight, the maximum total dry weight (3.37 g) was highest in 'large' which was closely followed by 'medium' (3.20 g). The total dry weight was only 2.72 g in case of 'small'. The above data clearly indicated the superiority of seedlings produced from 'large' and 'medium' sized pods over that of 'small'.

The same trend as observed in the December sown seedlings was noticed in the growth parameters during January to April also, except that the height was more in March and lowest in January. The length of tap root was higher in case of 'large' in all the months studied. But in case of 'medium' it was found to be higher than 'small' during the month of January alone. In all other months 'small' produced longer tap root. But the number of lateral roots were always higher in 'medium' compared to 'small'. The dry weight of root was also higher in general in the case of 'large' and 'medium' compared to the 'small'. Therefore, when taking into account of the growth parameters studied the seedlings produced from large and medium pods are found to be superior to those from small. This suggests that large and medium sized pods (weighing more than 350 g, with volume of not less than 400 cc) may be selected for propagation.

Data also suggest sowing in February and March for obtaining better seedlings. The earlier studies also indicated a better germination during this period. Additionally, the seedlings raised in February and March will be ready for planting in May and June which is the main planting season under Kerala conditions.

From the different growth parameters studied a set of selection criteria based on the height and the number of leaves produced is suggested. The seedlings should have not less then 30 cm height and not less than 10 leaves when they are 90 days old. Those which are below this standard should be rejected. However, the above criteria can be proved only after the bearing performance of the plants of varied groups are studied for which the seedlings have been planted in the field.

This result agrees with that of Cardosa (1963) who had studied the germination and growth of plants from the seeds taken from different position (top, center and bottom) in the pod. He also observed no difference in germination or in development of the seedlings based on the position of the seed within the pod.

1.4 Size of Containers

In the studies conducted in December, February and March with different sizes of containers (polythene bags), the height, the girth and the number of leaves produced were maximum for the seedlings grown in 30 x 20 cm bags and minimum for those grown in 23 x 15 cm bags. The growth was higher in February and March sowing.

Analysis of the data on root growth revealed that the tap root growth and lateral root production were maximum in the case of 30 x 20 cm bags and minimum in 23 x 15 cm bags. The dry matter accumulation in the shoot and the root were highest for the seedlings grown in 30 x 20 cm bags and lowest in those grown in 23 x 15 cm bags.

Thus it can be clearly said that the largest bag tried (30 x 20 cm lay flat) is most suitable for growing the seedlings in the nursery upto three months, as maximum vegetative growth and root growth as well as the dry matter accumulation was observed in the case of seedlings grown in these bags. This is natural because of the larger area for the root growth in big bags. The root extension growth data also reveal that the optimum size is 30 x 20 cm. Higher size naturally will be more expensive and hence not economical.

Several workers had investigated the optimum size of polythene bags or pots in relation to the growth of the plants. Capriles and Gonzalo (1965) found that the growth of cocoa seedlings in plastic bags of 15 cm diameter holding 6.0 kg of potting mixture was slightly better than that in smaller bags. LeBrown et al.(1967) recommended 12" x 7" (30 x 17.5cm) size polythene bags for raising cocoa seedlings. Leach et al. (1971) found polythene bags of 30 x 20 cm size as optimum in Malaysia when the period in the nursery was four to five months. They also recommended smaller size (23 x 18 cm or 25 x 18 cm) when the period in the nursery was two to two and a half months. Shepherd (1976) had given specific

recommendations on the size of the bags to the used depending upon the period to be retained in the nursery. According to him the optimum size would be 30 x 20 cm with 30 perforations for four to five months in the nursery and 25 x 18 cm with 20 perforations for three to four months in the nursery. Wood (1978) suggested 25 x 12 cm size for the seedlings upto five months in the nursery.

The present investigation agrees with the findings of Le Drown et al.(1967), Leach et al.(1971) and Shepherd(1976) but records slight variation from that of Capriles and Gonzalo (1965) and the suggestion of Wood (1978). In case of Capriles and Gonzalo (1965) the plastic bag is quite long as it has to hold 6.0 kg mixture which will be uneconomical under our conditions. The present investigation has taken into account not only the vegetative growth but also the root growth which is important in fixing the size of the polythene bags to be used in the nursery. If the polythene bag is smaller in size, the tap root will coil at the bottom of the bag and there will not be proper development of lateral roots which is quite evident from the Table 25. Under Kerala conditions, the seedlings are to be grown for a period of three to five months depending upon the planting time. Therefor for the best growth of plants an optimum polythene bag size of 30 x 20 cm is recommended.

1.5 Potting Medium

The statistical analysis of the vegetative growth characters under different media showed that the height, girth and number of leaves were significantly higher in December sowing and the height alone was significantly higher in March sowing in the seedlings grown in potting mixture composed of soil sand and farm yard manure in the proportion of 1:1:2. Though there was no significant difference in the growth characters of the February sowing, the maximum growth was recorded in the same treatment.

The data on root growth indicated that the top root length and the lateral root production were maximum for seedlings grown in the 1:1:2 potting mixture although it was not statistically significant. The dry matter accumulation in the root and the shoot was also highest for the seedlings grown in the same treatment.

The better growth recorded in soil sand and FYM mixture in the proportion of 1:1:2 is natural because of the better texture and resulting better drainage and aeration of the soil as well as the higher nutrient content in the medium. In soil medium, perhaps lack of sufficient nutrients, aeration and drainage limits the growth. But in case of the medium with low FYM (1:1:1) the low nutrient content may be responsible for comparatively low growth.

Only few workers have attempted to formulate a suitable potting mixture for the cocoa nursery. Pyke (1935) obtained best germination in calcareous sand. Whitehead (1954)

reported that a mixture of seven parts of loam, three parts of dried farm yard manure and two parts of sand for fairly uniform growth of seedlings. Wessel (1966) found better germination in heavy soils; but the subsequent growth was better in light soils. Shephard (1976) suggested a sandy-clay loam texture and a stable structure for the potting mixture to be used for cocoa seedlings. He also suggested incorporation of 20 per cent coarse sand and well decomposed FYM. Wood(1978) reported that in West Africa top soil alone was used for filling the bags. The above findings clearly indicate that the proportion of soil, sand and farm yard manure varied depending upon the soil types. But it reveals that a sandy loam texture with high percentage organic matter will be most suitable. The present study also, therefore, agrees in principle with the above findings. Considering our soil types a normal mixture of soil, sand and farm yard manure in the proportion of 1:1:2 is more suitable than the soil alone or a 1:1:1 mixture.

1.6 Viability of Seeds in Storage

Cocoa seed is non-resting and when the pod is ripe the seeds are also ready for germination. Cocoa seeds normally lose their viability after a comparitively short period of storage.

As against the normal germination in fresh sowing the present results showed that the seeds taken from the pods kept as such under room conditions showed the maximum

germination (78.02%) as compared to the normal germination when sown on the day of harvest after three days of storage. The germination was reduced to 66.29, 33.89 and 23.33 per cent 6, 9 and 12 days after harvest respectively.

The seeds extracted and then kept in polythene bags under room conditions showed 44.44 per cent germination after three days of storage and 20 per cent after six days. The seeds extracted and stored in polythene bags did not germinate after 9 days of storage.

There was no germination under refrigerated conditions even after three days when the pods were kept as such and also when the seeds were extracted and kept in polythene bags.

Few workers have studied the viability of cocoa seeds after storage. Pyke (1935) reported 95 per cent germination fourteen days after storage at an average temperature of 80°F. But storage at 50°F and 45°F destroyed viability even after two days, while a temperature of 60°F gave normal percentage of germination even after twenty days. He also suggested that the deterioration of pods under normal conditions are mainly due to desiccation, fungal attack and senescence. Zink and Rochelle (1964) obtained 72 per cent germination after 90 days when stored in ventilated glass containers with 40 per cent relative humidity, while the beans stored at 50°C failed to germinate even after 15 days. Woodstock et al.(1967) reported that the germinated seeds were killed by chilling

at 2 to 4°C for 30 minutes. The non-germination of the seeds stored under refrigerated conditions may be due to chilling as suggested by Pyke (1934), Pyke et al.(1934) and Woodstock et al.(1967). The present study indicates that it is better to sow the seed on the same day of extraction for obtaining higher percentage of germination; but the pods can be stored under room conditions even upto six days with upto 66 per cent germination.

1.7 Root Growth Studies

The root characters studied revealed that the growth of the tap root was at a faster rate upto 15 days (43.8%) and thereafter the growth rate decreased at slow rate upto 30th day. The growth from 30th to 90 days was comparatively very slow. Thereafter the growth was faster but at low rate than the first 15 days. The increase in the number of laterals also followed the same trend. The length of the lateral roots increased only gradually upto 60 days and thereafter at a much faster rate. The increase in dry matte accumulation in the root was at a slow rate upto 30 days and thereafter the increase was at a much faster rate upto 180 days. Then the rate of increase was reduced. The growth of roots and accumulation of dry matter in shoots and roots followed alternatively.

The slow root growth during the period between 90 and 120 days suggest that it will be advisable to plant the seedlings during this period for better and early growth in

the field. The tap root growth and the number of laterals at this stage will be reasonable to accommodate in the polythene bag or pot of the size 30 x 20 cm. The study also indicate that keeping the plants in the nursery in small bags, is not advisable as they become 'pot bound' by that time and it may lead to casualities in the main field.

Zevallos (1963) compared the growth of the shoot and root in the nursery and found that during the four months in the nursery, the relative length of shoot and root remained the same thereafter the shoot grew more rapidly. The present study reveals that the dry matter accumulation of the shoot was almost three times than that of the root. The height of the seedlings was always more than the tap root length at least by 25 to 83.5 per cent.

2. VEGETATIVE PROPAGATION

In order to standardise the methods of vegetative propagation, rooting of cuttings using plant growth regulators and four methods of budding were tried.

2.1 Rooting of Cuttings

The highest percentage of rooting in the 'mist chamber' method (96.3) was obtained for IAA 6000 ppm treated for 60 sec, closely followed by NAA 4000 ppm treated for 60 sec (94.9). These two treatments though on par were significantly superior to the rest. In the polythene sheet method also the highest percentage of rooting was obtained for IAA 6000 ppm 60 sec (85.8%) followed by NAA 4000 ppm 60 sec (80.6)

which were also significantly higher. The mean number of roots were 3.37 cm and 2.53 for IAA 6000 ppm and NAA 4000 ppm, respectively.

The number of roots was significantly higher for 6000 ppm NAA treated for 10 sec., but the percentage of rooting was very low (46). The mean number of roots were also found to vary significantly among the treatments. The mean number of roots increased with the concentration of plant growth regulators treated, upto 30 seconds and decreased thereafter except in a few cases. The average length of roots was found to be more in case of low concentration at short period of treatments (10 sec.) and decreased as the concentration was increased and time of treatment was prolonged.

The concentrations and time of treatments were found to be optimum for higher rooting at a particular level (6000 ppm IAA for 60 seconds, 4000 ppm NAA for 60 seconds) above which the percentage of rooting was found to decease. This is natural because the plant growth regulators have specificity in this action with reference to concentration and conditions under which treated.

Several workers have tried different plant growth regulators for increasing the rooting of cocoa cuttings. Richards (1948) found that IBA and NAA were effective in increasing the percentage of rooting and mean root length. According to Garcia and Maundorf (1950) IBA markedly increased the percentage of rooting and the number of roots.

Evans (1951) suggested quick dip method to be more convenient. According to him, the mixture of equal parts of NAA and IBA between 8000 and 10000 ppm were found more effective. Alvim and Duarte (1954) recommended 0.7 or 0.8 per cent IBA, while Edwards (1961) recorded best results with 8000 ppm IBA Cabato (1961) recommended NAA at 8000 ppm in powder form. Bouma and Ringling (1962) obtained 84 per cent rooting with 4000 ppm IBA while, Kailaram et al. (1964) obtained best results with a mixture of IBA and NAA at 5000 ppm.

The present investigation differs with those of the above workers with regards to the concentration and the type of plant growth regulator used. However, it agrees with the findings of Cabato (1961) who found NAA at 8000 ppm more suitable. The variation can be explained by the fact that the plant growth regulators are specific in their action at different concentrations under different conditions. Taking into account the higher percentage of rooting, optimum number of roots produced and the average length of roots a 'quick dip' method for 60 seconds in 4000 ppm of NAA or 6000 ppm of IAA is recommended.

Among the two methods tried the 'mist chamber' and the polythene sheet method (M.A.C.R.I. method) the percentage of rooting was higher for the 'mist chamber' method but the average number of roots and the average length of the roots were higher for the polythene sheet method.

The 'mist chamber' method requires spraying of water once a week while in the 'polythene sheet method' the watering has to be done once in three days. Thus though the initial investment in the mist chamber method is comparatively higher, the recurring expenditure will be less than in the polythene sheet method. Thus the 'mist chamber' method is recommended although both the methods can be used.

2.2 Budding

Four methods of budding, namely the 'T', the inverted 'T', the patch and the forkert methods were tried on seven to eleven month old root stocks. Among the methods tried, the forkert method gave the highest percentage of success (60.0) in February and in March when the budding was done on eight and nine month old root stocks followed by the inverted 'T' (45%) and the patch (40%).

Rosenquist (1952) reported 56 to 82 per cent success with patch budding. Topper (1956) developed an inverted 'T' budding and Liabeuf (1958), testing this method, obtained 50 to 80 per cent 'take' after top budding Chupons growing from previously cut back eight year old trees. Urquhart (1961) reported the use of shield budding on four month old cocoa seedlings. Ascenso (1968) obtained 50 to 80 per cent success with patch budding and 77 per cent with inverted 'T' method in Sao Tome. Van de Burg (1969) found that better results could be obtained by the forkert method if the flap was completely cut off from the stock. The

present finding also prove the superiority of forkert method over the other method and the percentage of success can further be improved by experience.

2.3 Green budding

The four methods of budding were also tried on younger root stocks of two to four months old.

The highest per cent of success was obtained by using buds from greenish brown twigs than from green buds. The highest per centage of success on budding done on two month old root stocks in March was 60 for forkert method. Hundred per cent success was obtained by forkert method on three month old root stocks and eighty per cent for 'inverted-T' in April while on four month old root stocks the highest per cent of success (80) was obtained for forkert and 'inverted-T' methods in May.

Topper (1959) developed a technique of greenbudding on three to four months old cocoa root stocks. This metho was subsequently improved by Murov (1961,1971) and used in Malaysia for budding of two to eight month old rubber seedlings. Thirion (1939), Paredes (1949), Are (1965,1967) Van de Burg (1969) and Magethaes (1974) found that cocoa can be budded successfully on four to five months old seedlings. According to Oldeberger and Coester (1976), forkert method is successful to the extent of 80 to 100 per cent in Netherlands under glasshouse conditions on

six weeks old root stocks. He suggested that four to five months old seedlings can be used as root stocks under tropical conditions. The present investigation has clearly proved that Forkert method can be successfully adopted for green budding on three to four months old stocks during the months of April and May, the best period being April. The green budding has added advantage that the period in the nursery is considerably reduced.

SUMMARY

SUMMARY

A detailed study was conducted during the period from May 1978 to July 1979 at the College of Horticulture, Vellanikkara, on different aspects of propagation of cocoa. The objectives of the investigations were (i) to standardise the criteria for selecting the pods, seeds and seedlings (ii) to find out the optimum size of polythene bags and to standardise the suitable potting medium for the nursery and (iii) to standardise the best vegetative propagation method. The results are summarised below.

1. The volume and weight of the pods varied among the three classes of pods namely, 'large', 'medium' and 'small' and also among the months of harvest.
2. The pods collected in December and February had comparatively higher volume and the pods harvested in December and April the highest weight.
3. The volume and weight were highest for large pods followed by medium and small.
4. There was not much variation in the number of seeds among the three classes of pods. The mean number of seeds per pod varied between 30 and 42.
5. The number of seeds were highest in pods harvested in February followed by March and April.

6. The weight of sound seeds as well as the mean weight of a sound seed were highest for 'large' pods followed by 'medium' and 'small' pods.

7. The weight of the sound seeds and the average weight of a sound seed were highest in pods harvested in February followed by March and April.

8. The size of the pod and the position of the seeds (pedicel end, middle and distal end) had no significant influence on the germination percentage.

9. The germination percentage was highest in March followed by February, January, December and April.

10. There was no significant difference, in general, by the third month in the vegetative growth parameters, root growth parameters and the dry matter accumulation when considering the size of pods and the position of the seed in the pod.

There was, in general, no correlation between the height of the seedlings on 15th and 30th day after germination and the pod characters such as length, girth, volume and weight of the pods.
But the 'large' and 'medium' pods showed comparatively better shoot and root growth. Therefore large and medium sized pods weighing more than 350g each with not less than 400 cc volume should be selected for raising nursery during the months of February and March.

11. From the different growth parameters studied based on the height and the number of leaves produced, a selection criterion is suggested for selecting quality seedlings. The seedlings should have not less than 30cm height and not less than 10 leaves when they are three months old.

12. Polythene bags of 30cmx20cm lay flat size are most suitable for growing the seedlings in the nursery for three to five months compared to 23 cm x 15 cm and 25cm x 18 cm sizes as the seedlings grown in these bags are superior in height, girth and the number of leaves produced. These seedlings are also found to produce better root system.

13. A normal mixture of soil, sand and farm yard manure in the proportion of 1:1:2 is recommended for growing seedlings in the nursery.

14. The seeds may be sown on the same day of extraction for maximum percentage of germination. The percentage of germination is decreased as the days after harvest is advanced. But the pods can be stored upto six days under room conditions with 66 per cent germination.

15. The root growth studies conducted periodically on seedlings upto nine months had indicated that the root growth is maximum during the first fortnight

after germination and thereafter the rate of growth is comparatively decreased and the growth was very slow between 30 to 90 days. The possibility of taking advantage of slow growth of roots between three to four months for planting was discussed.

16. The root growth and the dry matter accumulation was found to be alternated, that is, when high shoot growth rate was recorded, the accumulation of dry matter was low and the same was increased considerably when the shoot growth was slow.

17. Taking into account of the higher percentage of rooting, optimum number of roots produced and the average length of roots, a 'quick dip' method for 60 sec in 4000 ppm NAA or 6000 ppm IAA is recommended for producing rooted cuttings.

18. The merits and demerits of the two methods, that is, the 'mist chamber' and 'polythene sheet method' were discussed and the 'mist chamber'method is recommended.

19. Among the different method of budding tried, 60 per cent success was obtained in forkert method when budded on eight to nine month old root stocks. The best time for budding was found to be between February to April.

20. Green budding on three to four months old cocoa seedling stock was found to give 80 to 100 per cent success with forkert method. April and May were found to be the best time for green budding with 100 per cent success in April. Hence green budding in April and May on three to four months old seedlings is recommended.

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* Originals not seen.

APPENDIX - I

Analysis of variance for percentage of germination in different months.

Source	df	Mean squares				
		Month of sowing				
		December	January	February	March	April
Pod size	2	120.93	164.92	165.71	47.84	238.64
Seed position	2	422.48	26.05	1008.56	194.39	44.26
Interaction	4	35.29	58.99	60.59	74.17	94.65
Error	18	114.43	337.06	212.76	116.78	203.19

APPENDIX - II

Analysis of variance for height of seedlings at various intervals.

Month	Source	df	Mean squares					
			Days after germination					
			15	30	45	60	75	90
December	Size	2	12.33*	16.13**	123.27**	66.08*	131.03	66.15
	Position	2	2.33	5.49	9.80*	7.80*	108.01	101.68
	Interaction	4	16.52*	8.84**	38.99*	32.50	172.42**	86.03
	Error	18	5.29	3.45	7.50	1.38	94.03	96.88
January	Size	2	7.50	9.70	6.90	5.20	19.16	22.51
	Position	2	0.98	0.01	1.63	0.68	1.50	2.65
	Interaction	4	3.98	1.30	1.26	13.99	10.87	8.87
	Error	18	2.17	3.95	2.64	21.07	16.97	8.62
February	Size	2	4.84	10.78	16.03	0.94	2.63	22.4
	Position	2	0.58	2.38	1.47	15.37	20.97	30.84
	Interaction	4	0.45	1.47	1.10	6.20	11.51	27.83
	Error	18	2.98	8.56	5.53	7.42	14.56	66.01
March	Size	2	2.59	10.74*	0.64	5.10	1.48	147.12
	Position	2	2.57	1.28	0.26	2.09	16.99	13.73
	Interaction	4	1.69	1.49	2.96	6.62	5.15	9.65
	Error	18	1.89	2.80	7.19	8.67	14.51	22.84
April	Size	2	3.69	9.54	2.19	9.03	47.28	4.80
	Position	2	1.21	11.01	13.35	5.45	16.28	0.45
	Interaction	4	1.74	5.69	2.40	2.41	8.28	5.33
	Error	18	4.84	17.85	5.69	4.85	19.44	11.58

* Significant at 5% level.
** Significant at 1% level.

APPENDIX - III

Analysis of variance for girth of seedlings at various intervals in different months.

Month of sowing	Source	df	Mean squares					
			Days after germination					
			15	30	45	60	75	90
December	Size	2	0.07	0.002	123.27**	66.08**	131.03	66.15
	Position	2	0.01	0.012	9.80*	7.80	108.01	101.68
	Interaction	4	0.01	0.013	38.99**	32.50**	172.42	86.03
	Error	18	0.04	0.013	7.50	1.38	94.03	96.80
January	Size	2	0.04	0.002	0.002	0.001	0.015	0.01
	Position	2	0.02	0.001	0.001*	0.001	0.003	0.019
	Interaction	4	0.01	0.001	0.001	0.01	0.005	0.00
	Error	18	0.01	0.001	0.001	0.01	0.013	0.00
February	Size	2	0.001	0.03**	0.001	0.002	0.003	0.01
	Position	2	0.006	0.01	0.01	0.001	0.002	0.05
	Interaction	4	0.009	0.01	0.001	0.001	0.01	0.03
	Error	18	0.015	0.01	0.01	0.01	0.02	0.01
March	Size	2	0.005	0.002	0.02	0.01	0.05**	0.08
	Position	2	0.003	0.003	0.002	0.003	0.004	0.08
	Interaction	4	0.004	0.002	0.024	0.02	0.002	0.03
	Error	18	0.002	0.005	0.011	0.02	0.003	0.06
April	Size	2	0.003	0.001	0.001	0.001	0.17*	0.00
	Position	2	0.001	0.003	0.003	0.001	0.09	0.00
	Interaction	4	0.002	0.001	0.001	0.002	0.01	0.00
	Error	18	0.003	0.004	0.004	0.02	0.02	0.00

* Significant at 5% level
** Significant at 1% level

APPENDIX - IV

Analysis of variance for number of leaves at various intervals in different months.

Month of sowing	Source	df	Mean squares					
			Days after germination					
			15	30	45	60	75	90
December	Pod size	2	0.26	0.46	0.96**	2.32**	1.41	3.30
	Seed position	2	0.49	0.59	0.12	0.63	0.18	3.86*
	Inter-action	4	0.24	0.78	1.28**	3.53**	1.02	0.29
	Error	18	0.15	0.49	0.13	0.40	0.97	0.94
January	Pod size	2	0.0001*	0.40	0.21	1.27	0.15	2.58
	Seed position	2	0.083	0.75	0.85	1.13	0.40	3.95
	Inter-action	4	0.051	0.46	0.19	0.47	2.48	5.16
	Error	18	0.123	0.26	0.21	1.23	2.67	3.96
February	Pod size	2	0.093	1.44	1.25**	0.20	1.85	5.00
	Seed position	2	0.031	1.12	0.38	6.46	1.61	1.41
	Inter-action	4	0.024	0.04	0.77	1.04	1.30	0.52
	Error	18	0.17	0.13	0.62	1.90	1.58	1.50
March	Pod size	2	0.16	0.61	0.28	0.27	0.30	0.68
	Seed position	2	0.13	1.59*	0.07	0.33	0.82	4.13
	Inter-action	4	0.03	0.63	0.78	0.16	0.04	2.80
	Error	18	0.24	0.45	1.22	1.30	2.38	4.04

APPENDIX - IV CONTINUED.

Month of sowing	Source	df	Mean squares					
			Days after germination					
			15	30	45	60	75	90
April	Pod size	2	3.69	0.70	0.24	2.20	0.39	1.38
	Seed position	2	1.21	0.82	2.06	5.76	3.37	0.75
	Inter-action	4	1.74	1.05	1.64	0.49	2.52	0.3
	Error	18	4.84	0.83	2.11	1.82	1.36	1.9

APPENDIX - V

Analysis of variance for length of tap root at various intervals in different months.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Pod size	2	2.35	24.49**	76.77*
	Seed position	2	3.19	4.78*	13.51
	Interaction	4	5.51*	2.41	23.42
	Error	18	1.73	1.13	19.29
January	Pod size	2	0.24	1.60	2.90
	Seed position	2	1.14	2.10	1.22
	Interaction	4	0.76	5.04	4.45
	Error	18	2.66	11.80	5.80
February	Pod size	2	0.54	0.07	6.41
	Seed position	2	5.53	3.16	2.77
	Interaction	4	0.19	2.35	8.62
	Error	18	4.51	10.75	8.21
March	Pod size	2	0.58	0.75	31.55
	Seed position	2	5.54	9.89	0.92
	Interaction	4	3.40	11.99	10.55
	Error	18	3.07	7.09	10.64
April	Pod size	2	2.71	0.91	5.1
	Seed position	2	0.07	0.77	6.48
	Interaction	4	1.75	1.11	5.28
	Error	18	7.43	3.40	8.22

* Significant at 5% level.
** Significant at 1% level.

APPENDIX-VI

Analysis of variance for length of the longest lateral root at various intervals in different months.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Pod size	2	0.16	1.62**	13.7
	Seed position	2	0.47	2.43**	3.6
	Interaction	4	0.90	3.09**	7.4
	Error	18	0.40	0.13	4.5
January	Pod size	2	0.75	0.49	2.85
	Seed position	2	2.51	2.15	7.73
	Interaction	4	0.71	0.99	6.63
	Error	18	0.52	2.12	8.38
February	Pod size	2	3.82*	2.62	13.71
	Seed position	2	2.10	1.68	1.12
	Interaction	4	1.04	0.25	9.20
	Error	18	0.37	1.08	4.82
March	Pod size	2	1.10	4.72	14.12
	Seed position	2	0.96	5.68	11.33
	Interaction	4	0.68	1.84	3.62
	Error	18	0.31	7.66	20.48
April	Pod size	2	0.87	0.17	5.68
	Seed position	2	0.99	0.80	5.55
	Interaction	4	0.86	0.71	11.54
	Error	18	0.46	1.03	3.18

* Significant at 1% level.
** Significant at 5% level.

APPENDIX - VII

Analysis of variance for number of lateral roots at various intervals in different months.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Pod size	2	2.65	1095.93*	9435.42**
	Seed position	2	4.14	79.57	270.29
	Interaction	4	15.00	82.53	1145.02
	Error	18	11.33	235.14	611.15
January	Pod size	2	6.77	55.11	18.92
	Seed position	2	14.77	40.11	3.37
	Interaction	2	38.22	39.88	34.75*
	Error	18	19.37	51.48	11.33
February	Pod size	2	2.70	305.77*	246.32
	Seed position	2	101.91*	13.00	87.61
	Interaction	4	23.81	95.11	77.72
	Error	18	19.08	53.48	97.20
March	Pod size	2	11.33	56.25**	32.33
	Seed position	2	26.42	16.59	12.00
	Interaction	4	6.44	19.09*	48.00
	Error	18	21.48	5.74	27.89
	Pod size	2	29.03	7.58	1.58
	Seed position	2	9. 14	5.08	0.03
	Interaction	4	31.48	14.83	13.81*
	Error	18	10.20	12.69	6.77

* Significant at 5% level.
** Significant at 1% level.

APPENDIX - VIII

Analysis of variance for dry weight of shoot at various intervals in different months.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Pod size	2	91581.8*	104023.4**	716845.4
	Seed position	2	151549.8**	144004. 1**	207500.9
	Interaction	4	22459.6	56204.1**	75334 .3
	Error	18	22614.5	11702.2	265606.5
January	Pod size	2	3665.7	48733.6	89224.8
	Seed position	2	90697.7	12624.2	3062 .1
	Interaction	4	36505.9	62362.2	123960.7
	Error	18	15063.8	91189.6	149537.1
February	Pod size	2	169559.8**	225232.3*	2670445.4**
	Seed position	2	72608.5*	95160.7	168808.6
	Interaction	4	35081.6	47238.2	534204.4
	Error	18	19593.4	51568.4	440022.9
March	Pod size	2	6832.0	330588.0*	3251027.7**
	Seed position	2	112675.4	26048.0	2453451.3*
	Interaction	4	66608.9	78146.5	1480892.8
	Error	18	41128.7	62949.8	409345. 8
April	Pod size	2	11700.0	116780.4**	2781237.9**
	Seed position	2	33141.1	87132.4**	61673. 9
	Interaction	4	25318.7	29020.2	220165. 0
	Error	18	28700.4	10072.9	438558.8

* Significant at 5% level.
** Significant at 1% level.

APPENDIX - IX

Analysis of variance for dry weight of root at various intervals in different months.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Pod size	2	792.5	1548.5	7629.2
	Seed position	2	4671.6	2318.8	2716.2
	Interaction	4	759.9	4424.4	7317.1
	Error	18	3599.6	4687.4	8544.6
January	Pod size	2	16.7	14003.7*	6942.4
	Seed position	2	826.9	300.2	13290.5
	Interaction	4	1664.5	889.6	21998.7
	Error	18	3825.3	2720.6	28677.2
February	Pod size	2	441.0	19276.3*	65858.8*
	Seed position	2	1117.5	3298.6	4326.5
	Interaction	4	525.9	2183.2	14294.1
	Error	18	349.7	2098.2	13878.1
March	Pod size	2	1352.7	4449.9	149236.0**
	Seed position	2	4228.1	12821.4*	73649.3
	Interaction	4	12496.9	4874.3	42290.7
	Error	18	4924.1	2852.9	21666.9
April	Pod size	2	12640.7**	6622.4*	340773.8**
	Seed position	2	1204.4	5147.7*	27971.8
	Interaction	4	911.5	3698.4	12695.9
	Error	18	793.6	1200.0	34751.6

* Significant at 5% level.
** Significant at 1% level.

APPENDIX - X

Analysis of variance for total dry weight at various intervals in different months.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Pod size	2	75412.3	103275.3*	866997.3
	Seed position	2	205818 .0*	141772.3**	246283.2
	Interaction	4	30621. 0	78768.1 *	120534.7
	Error	18	35023.3	22568.9	329890.7
January	Pod size	2	3232.5	110884.1	73096.1
	Seed position	2	95704.8	14734. 4	28185.6
	Interaction	4	45706.5	69758. 8	194716.4
	Error	18	26482.7	106160. 3	240383.5
February	Pod size	2	187002.4**	273236.1*	3470313.8*
	Seed position	2	89492.9*	101945.6	207554 .2
	Interaction	4	43419.8	44148.7	720742. 0
	Error	18	21945.9	59296.7	577766.6
March	Pod size	2	14010.9	273090.0*	4570669.9*
	Seed position	2	153229.4	46689.1	3263073.6*
	Interaction	2	73418.6	108517.8	1774804.6
	Error	4	54645.1	75637.7	547051.7
April	Pod size	2	196.3	132708.6*	5060696.8*
	Seed position	2	37270.3	132708.6**	99354. 1
	Interaction	2	28809.3	33047.7	298559.6
	Error	18	30530.4	13981. 3	683460. 7

* Significant at 5% level.
** Significant at 1% level.

APPENDIX - XI

Analysis of variance for height of seedlings at various intervals in different sizes of bags

Month of sowing	Source	df	Mean squares					
			Days after germinations					
			15	30	45	60	75	90
December	Treatments	2	107.54**	47.35	25.54	12.48	177.52*	175.14**
	Error	12	12.08	13.69	10.29	9.00	28.82	22.09
February	Treatments	2	12.15	49.31	27.38	353.76**	165.64	83.60
	Error	12	4.09	10.34	3.52	26.67	45.09	33.20
March	Treatments	2	11.09	28.95	43.90	45.91	39.11	232.66**
	Error	12	2.93	14.59	14.05	46.60	25.19	36.22

* Significant at 5% level.

** Significant at 1% level.

APPENDIX - XII

Analysis of variance for girth of seedlings at various intervals in different sizes of bags.

Month of sowing	Source	df	Mean squares					
			Days after germination					
			15	30	45	60	75	90
December	Treatments	2	0.02	0.11	0.08	0.14	0.34**	0.36**
	Error	12	0.02	0.06	0.05	0.04	0.03	0.03
February	Treatments	2	0.001	0.05*	0.02	0.10	0.06	0.11
	Error	12	0.01	0.01	0.04	0.04	0.04	0.04
March	Treatments	2	0.02	0.10**	0.25*	0.06	0.11	0.12
	Error	12	0.01	0.01	0.04	0.07	0.06	0.06

* Significant at 5% level.
** Significant at 1% level.

APPENDIX - XIII

Analysis of variance for number of leaves produced in different sizes of bags.

Month of sowing	Source	df	Mean squares					
			Days after germination					
			15	30	45	60	75	90
December	Treatments	2	2.60**	1.86	6.06	5.06	1.40	9.80
	Error	12	0.26	0.76	1.56	3.40	4.30	1.40
February	Treatments	2	0.06	1.06	6.06*	2.46	1.40	6.06
	Error	12	0.06	0.93	1.06	2.20	4.30	2.80
March	Treatments	2	1.86**	0.26	8.60	5.60	8.60	0.46
	Error	12	0.26	0.93	4.43	1.53	4.43	2.50

* Significant at 5% level.
** Significant at 1% level.

APPENDIX - XIV

Analysis of variance for length of tap root in different sizes of bags.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Treatments	2	1.88	7.07	3.28
	Error	12	4.41	5.94	29.62
February	Treatment	2	5.56	19.61	1.03
	Error	12	3.32	12.64	12.53
March	Treatments	2	0.99	11.59	7.32
	Error	12	3.42	15.52	28.00

APPENDIX-XV

Analysis of variance for length of longest lateral root in different sizes of bags.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Treatments	2	1.06	2.23	54.72*
	Error	12	0.77	2.87	10.70
February	Treatments	2	1.20	19.71*	22.73
	Error	12	0.64	4.78	8.59
March	Treatments	2	0.36	24.73*	6.79
	Error	12	0.43	4.12	21.70

* Significant at 5% level.

APPENDIX - XVI

Analysis of variance for number of laterals in different sizes of bags.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Treatments	2	62.46**	455.00**	545.00
	Error	12	2.50	53.33	89.16
February	Treatments	2	70.86**	1.66	31.66
	Error	12	3.83	35.00	47.50
March	Treatments	2	50.46**	45.00	380.00
	Error	12	2.66	87.50	140.83

** Significant at 1% level.

APPENDIX - XVII

Analysis of variance for dry weight of shoot in different sizes of bags.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Treatments	2	39621.7	125166.7	171500.0
	Error	12	12766.7	172333.3	321833.3
February	Treatments	2	34586.7	169820.0	137040.0
	Error	12	11050.00	188800.0	316596.7
March	Treatments	2	28445.0	166051.7	139606.7
	Error	12	8116.7	205126.7	464043.3

APPENDIX - XVIII

Analysis of variance for dry weight of root in different sizes of bags.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Treatments	2	8211.7	15011.7	49221.7**
	Error	12	18750.0	4791.7	5378.3
February	Treatments	2	13020.0	43291.7*	26446.7
	Error	12	7550.0	9816.7	15353.3
March	Treatments	2	18006.7	6986.7	3846.7
	Error	12	15710.0	7026.7	6229.2

* Significant at 5% level.
** Significant at 1% level.

APPENDIX - XIX

Analysis of variance for total dry weight in different sizes of bags.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Treatments	2	13206.7	219345.00	395071.7
	Error	12	26500.8	166583.3	337986.7
February	Treatments	2	90046.7	387015.0	252326.7
	Error	12	14333.3	224896.7	342010.0
March	Treatments	2	83585.0	237421.7	189646.7
	Error	12	29226.7	199873.3	445045.8

* Significant at 5% level.

APPENDIX - IX

Analysis of variance for height of seedlings in different media.

Month of sowing	Source	df	Mean squares					
			Days after germination					
			15	30	45	60	75	90
December	Treatments	2	0.41	40.92**	15.40	23.23	110.22*	93.56
	Error	12	6.07	5.38	3.41	11.84	16.19	12.77
February	Treatments	2	22.42*	20.64**	13.89	28.29	23.43	16.66
	Error	12	3.90	1.48	4.34	54.59	79.59	91.09
March	Treatments	2	0.26	49.95**	22.62	78.30	104.93	110.18
	Error	12	4.95	4.62	13.57	37.94	32.13	44.46

* Significant at 5% level.

** Significant at 1% level.

APPENDIX - XXI

Analysis of variance for girth of seedlings in different potting media.

Month of sowing	Source	df	Mean squares					
			Days after germination					
			15	30	45	60	75	90
December	Treatments	2	0.08	0.003	0.06	0.20*	0.08	0.12
	Error	12	0.08	0.01	0.03	0.03	0.03	0.16
February	Treatments	2	0.001	0.002	0.06	0.06	0.03	0.11
	Error	12	0.01	0.004	2.04	0.06	0.03	0.06
March	Treatments	2	0.06	0.002	0.06	0.16	0.07	0.01
	Error	12	0.07	0.01	0.09	0.11	0.06	0.02

* Significant at 5% level.

APPENDIX - XXII

Analysis of variance for number of leaves produced in different media.

Month of sowing	Source	df	Mean squares					
			Days after germination					
			15	30	45	60	75	90
December	Treatments	2	0.20	0.26	0.80	12.20**	21.66	21.06
	Error	12	0.16	1.40	1.36	0.96	3.49	7.06
February	Treatments	2	0.36	0.06	0.60	19.40	12.06	7.26
	Error	12	0.26	1.06	1.06	7.06	4.56	6.26
March	Treatments	2	0.20	0.26	4.06	14.06	12.06	20.26
	Error	12	0.16	1.40	5.06	3.73	5.23	6.03

** Significant at 1% level.

APPENDIX-XXIII

Analysis of variance for length of tap root in different media.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Treatments		13.76	18.22	112.52
	Error	12	9.57	6.71	33.06
February	Treatments	2	9.31	58.50	52.84
	Error	12	6.69	22.45	40.17
March	Treatments	2	9.99	55.54	38.89*
	Error	12	6.27	25.79	9.58

* Significant at 5% level.

APPENDIX - XXIV

Analysis of variance for the length of the longest lateral

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Treatments	2	0.68	1.68	31.33
	Error	12	0.47	3.10	27.11
February	Treatments	2	0.68	14.61	60.26*
	Error	12	0.45	10.05	3.75
March	Treatments	2	0.68	7.11	10.53
	Error	12	0.40	6.89	7.81

* Significant at 5% level.

APPENDIX - XXV

Analysis of variance for number of laterals produced in different media.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Treatments	2	42.06	331.66	1131.66
	Error	12	12.73	321.66	309.16
February	Treatments	2	42.06	21.66	15.00
	Error	12	12.40	112.50	46.66
March	Treatments	2	42.06*	245.00	375.00
	Error	12	8.56	45.83	124.16

* Significant at 5% level.

APPENDIX - XXVI

Analysis of variance for dry weight of shoot in difference media.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Treatments	2	50006.7	114980.0*	953166.7
	Error	12	31593.3	22853.3	1040250.0
February	Treatments	2	39795.0	375166.7	115406.7
	Error	12	22338.3	296166.7	186826.7
March	Treatments	2	730835.0*	730835.0	330646.7
	Error	12	184470.0	184470.0	641716.7

* Significant at 5% level.

APPENDIX-XXVII

Analysis of variance for dry weight of root in different media.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Treatments	2	7786.7	5135.0	71820.(
	Error	12	3800.0	10480.3	34463.
February	Treatments	2	6660.0	13140.0	103280.(
	Error	12	3810.0	12990.0	26383.3
March	Treatments	2	7980.0	21446.7	20271.7
	Error	12	2923.3	9883.3	9100.0

APPENDIX - XXVIII

Analysis of variance for total dry weight in different media.

Month of sowing	Source	df	Mean squares		
			Days after germination		
			30	60	90
December	Treatments	2	82460.0	160351.7*	1389786.7
	Error	12	36705.8	2948.2	1212080.0
February	Treatments	2	65845.0	523606.7	412326.7
	Error	12	28529.2	307206.7	168853.3
March	Treatments	2	95286.7*	1002351.7	483571.7
	Error	12	48710.0	256723.3	647740.0

* Significant at 5% level.

APPENDIX - XXIX

Analysis of variance for percentage of rooting and mean number of roots.

Mist Chamber Method.

Source	df	Mean squares	
		Percentage of rooting	Mean number of roots
Treatments (Grwoth regulators and concentration)	15	2222.05**	1.23**
Time	3	95.13	0.67**
Interaction	45	260.43**	0.47**
Error	128	90.36	0.04

** Significant at 1% level.

APPENDIX - XXX

Analysis of variance for percentage of rooting and mean number of roots.

Polythene Sheet Method.

Source	df	Mean squares	
		Percentage of rooting	Mean number of roots
Treatments (Grwoth regulators and concentrations)	15	1994.46**	1.99**
Time	3	19.45	0.42**
Interaction	45	242.42**	0.38**
Error	128	101.20	0.06

** Significant at 1% level.

APPENDIX - XXXI

Correlation coefficient of seedling and pod characters of large pods.

Month of sowing	Seedling characters	Pod characters			
		Length	Girth	Volume	Weight
December	Height on 15th day	+ 0.181^{NS}	+0.499^{NS}	+ 0.307^{NS}	+ 0.437^{NS}
	Height on 90th day	+ 0.201^{NS}	-0.326^{NS}	-0.453^{NS}	- 0.154^{NS}
January	Height on 15th day	+ 0.028^{NS}	+ 0.110^{NS}	- 0.364^{NS}	- 0.028^{NS}
	Height on 90th day	+ 0.024^{NS}	-0.224^{NS}	-0.371^{NS}	-0.598^{NS}
February	Height on 15th day	-0.294^{NS}	-0.239^{NS}	-0.311^{NS}	-0.170^{NS}
	Height on 90th day	+0.431^{NS}	+0.633*	+0.494^{NS}	+0.641*
March	Height on 15th day	+0.480^{NS}	+0.086^{NS}	+0.540^{NS}	+0.344^{NS}
	Height on 90th day	+0.512^{NS}	+0.301^{NS}	+0.753*	+0.669*
April	Height on 15th day	-0.406^{NS}	+0.280^{NS}	+0.059^{NS}	+0.337^{NS}
	Height on 90th day	+0.019^{NS}	-0.370^{NS}	-0.372^{NS}	-410^{NS}

NS Not significant.
* Significant at 5% level.

APPENDIX - XXXII

Correlation coefficients of seedling and pod characters of medium pods.

Month of sowing	Seedling characters	Pod characters			
		Length	Girth	Volume	Weight
December	Height on 15th day	+ 0.266^{NS}	- 0.318^{NS}	-0.266^{NS}	- 0.216^{NS}
	Height on 90th day	- 0.004^{NS}	- 0.042^{NS}	-0.290^{NS}	- 0.019^{NS}
January	Height on 15th day	- 0.080^{NS}	+ 0.401^{NS}	-0.109^{NS}	- 0.481^{NS}
	Height on 90th day	+ 0.124^{NS}	+ 0.501^{NS}	+0.225^{NS}	- 0.050^{NS}
February	Height on 15th day	- 0.065^{NS}	+ 0.040^{NS}	+ 0.060^{NS}	- 0.248^{NS}
	Height on 90th day	- 0.801**	+ 0.254^{NS}	+ 0.115^{NS}	- 0.133^{NS}
March	Height on 15th day	- 0.102^{NS}	+ 0.135^{NS}	+ 0.276^{NS}	- 0.331^{NS}
	Height on 90th day	+ 0.482^{NS}	- 0.201^{NS}	+ 0.151^{NS}	- 0.097^{NS}
April	Height on 15th day	-0.427^{NS}	+ 0.410^{NS}	+ 0.310^{NS}	- 0.0110^{NS}
	Height on 90thday	+0.073^{NS}	-0.632*	-0.742*	- 0.599^{NS}

NS Not significant.
* Significant at 5% level.
** Significant at 1% level.

APPENDIX-XXXIII

Correlation coefficients of seedlings and pod characters of small pods.

Month of sowing	Seedling characters	Pod characters			
		Length	Girth	Volume	Weight
December	Height on 15th day	+0.047^{NS}	-0.047^{NS}	-0.377^{NS}	-0.073^{NS}
	Height on 90th day	-0.142^{NS}	+0.258^{NS}	+0.238^{NS}	+0.002^{NS}
January	Height on 15th day	-0.523^{NS}	+0.320^{NS}	-0.186^{NS}	+0.002^{NS}
	Height on 90th day	+0.268^{NS}	-0.310^{NS}	+0.061^{NS}	-0.132^{NS}
February	Height on 15th day	+0.313^{NS}	+0.014^{NS}	+0.302^{NS}	+0.290^{NS}
	Height on 90th day	+0.435^{NS}	+0.209^{NS}	+0.181^{NS}	+0.048^{NS}
March	Height on 15th day	-0.515^{NS}	-0.294^{NS}	-0.217^{NS}	-0.418^{NS}
	Height on 90th day	-0.193^{NS}	-0.621^{NS}	-0.706*	-0.495^{NS}
April	Height on 15th day	+0.120^{NS}	+0.169^{NS}	+0.192^{NS}	+0.195^{NS}
	Height on 90th day	+0.349^{NS}	+0.448^{NS}	+0.551^{NS}	+0.128^{NS}

NS Not significant.
* Significant at 5% level.

PROPAGATIONAL STUDIES ON COCOA

(*Theobroma cacao* L.)

BY

R. KESHAVACHANDRAN

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the

requirements for the degree of

Master of Science in Horticulture

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COLLEGE OF HORTICULTURE

Vellanikkara - Trichur

1979

ABSTRACT

A study on the different aspects of propagation of cocoa was undertaken at the College of Horticulture from May 1978 to July 1979 to standardise the criteria for selecting the pods, seeds and seedlings for raising the nursery, to find out the optimum size of polythene bags and the suitable medium for raising the nursery and also to standerdise the best vegetative propagation methods for cocoa.

The results had indicated that the volume and weight of the pods varied within the three classes of pods namely large, medium and small. There was not much variation in the number of seeds among the three classes of pods and the mean number varied between 30 to 42. The number of seeds were found to be highest in pods harvested in February and March followed by April. The highest percentage of germination was recommended in March followed by February, January, December and April.

The size of the pod and the position of seeds(pedicel end, middle and distal end) had no significant influence on the germination and the growth of the seedlings.However, the large and medium sized pods are found to produce better seedlings. Based on the studies the following

recommendation are made i) Large and medium sized pods weighing more than 350g each with not less than 400 cc volume should be selected for raising the nursery during the month of February and March. ii) The seed should be sown on the same day of harvest but it can be stored under room conditions upto six days. The percentage of germination will be decreased to 66 per cent by the sixth day. iii) A selection criterion for selecting the seedlings when they are three months old is recommended. The seedlings should have atleast 30cm height and 10 or more number of leaves when they are three months old.

For raising three to five month old seedlings, the optimum size of bag is found to be 30 x 20 cm and the best medium for raising cocoa nursery is a mixture soil, sand and farm yard manure in the proportion 1:1:2.

Considering the pattern and extent of root and shoot growth of the seedlings, planting the seedling when they are three to four months old is suggested.

For higher percentage of rooting and optimum number of roots and higher root length, a 'quick dip' method for 60 sec in 4000 ppm NAA or 6000 ppm IAA is recommended for producing rooted cuttings. A 'mist chamber' method is suggested for rooting the cuttings.

Forkert method of budding is recommended for cocoa either on eight to nine months old root-stocks or by green budding on three to four months old root-stock. The best time for budding is February and March on older root-stocks and April and May for green budding.