CONTRIBUTION TO CACAO CUTTAGE

by

Louis L. de Verteuil

Inter-American Institute of Agricultural Sciences,
Turrialba, Costa Rica

July 11, 1956

CONTRIBUTION TO CACAO CUTTAGE

A Thesis

Submitted to the Faculty Committee in partial fulfillment of the requirements for the degree of

__Magister Agriculturae__

at the

Inter-American Institute of Agricultural Sciences

APPROVED:

Adviser

Committee

Committee

Committee

July 11, 1956

ACKNOWLEDGEMENT

The author wishes to express his sincere thanks and appreciation to Dr. Joseph Orsenigo for his valuable help and advice during the course of this project.

To Dr. Jorge León, Dr. Pierre Sylvain and Mr. Donald Fiester, who served on the special committee, for their generous assistance.

To Mr. Arnold Erickson for his material help in matters pertaining to the propagation house, and

To Miss Maria Teresa Cunillera for typing this manuscript.

BIOGRAPHICAL SKETCH

The auther was born on 31 March, 1912 in Trinidad, B.W.I. His primary and secondary education was received at St. Mary's College, Trinidad, B.W.I., where he obtained the Higher Certificate of Oxford and Cambridge (Science).

He attended the Imperial College of Tropical Agriculture, Trinidad, B.W.I., from 1929-32, and was graduated with the Diploma.

The author is a member of Her Majesty's Overseas Civil Service (Agriculture) and has served in the Caribbean area and West Africa.

He was on active service in World War II from 1939 to 1942 and served with the Royal West African Frontier Force in the Ethiopia and Somaliland campaigns, and attained the rank of Lieutenant.

The author's present appointment is Cocoa Agronomist, Department of Agriculture, Trinidad, B.W.I.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Cuttage has been in common use since the beginnings of agriculture as a means of vegetative propagation. There is no record, however, of its application to cacao prior to 1931 when Pyke (11) worked out a method of rooting cacao cuttings. The commercial use of cacao cuttage commenced in 1945 when the first plants were distributed to growers from the La Pastora Station in Trinidad, B.W.I. This was followed by similar developments in other cacao-growing territories of the Western Hemisphere.

It was agreed by the authorities concerned that the writer should undertake a reconnaissance survey of recent developments to evaluate the methods in current use and to ascertain the most promising lines for further invdstigation. In addition he would also carry out a research project at the Inter-American Institute of Agricultural Sciences to be determined by the information obtained in the survey.

The present position of cacao cuttage in the Western Hemisphere has been evaluated (5)*. This stidy has shown that the commercial porduction of clonal cacao is based entirely on cuttage and that some 9.000.000 plants had been produced by this method of vegetative propagation by the end of 1955.

It was further shown that the majority of the plants were produced by the closed-bin system, the efficiency of which was largely determined by the post-rooting treatment of the plant. The La Reunion method of propagation using the pot-rooting technique was twenty percent more

---

* The survey and report cited constitute partial fulfillment of the residence and thesis requirements.

efficient than the conventional closed bin-system when compared on the same station. The pot-rooting method offers certain decided advances over all the other methods presently in use and its wider application could result in an overall increase of propagation efficiency. At the same time it was desirable to evaluate this method under controlled conditions and compare it with the conventional method in common use.

In the process of converting a cutting into a plant, losses in the order of 30 percent to 70 percent are sustained. These losses occur during both the rooting phase and the post-rooting vegetative phase. It is not possible, however, to apportion accurately how much of these losses are occasioned by the improper application of known principles and how much to a lack of fundamental knowledge of the science and art of cacao cuttage. It is clear however, that losses occur which at present cannot be prevented through lack of the understanding of their nature.

A review of the literature reveals what the survey has indicated i.e. that whilst the external factors for rooting of cacao cuttings have been well defined there still remains much to be discovered about the role of the cutting itself in rooting. Experience with other crops has shown that rooting behaviour of cuttings can be influenced by their source and position on the source plant.

In the light of the foregoing it was decided that the research project would comprise experiments to evaluate the pot-rooting technique, and the effect on rooting efficiency of the source and position of the cutting on the tree. This thesis described such experiments.

REVIEW OF LITERATURE

The principal literature pertinent to the effects of external and internal factors in root formation on cacao cuttings is discussed below.

A. External Factors

The factors of temperature, light, and humidity are reported to be closely related to each other in the management of the propagators.

Pyke (11) stated that the ideal temperature should be high enough to stimulate callus growth, but low enough to avoid excessive respiration, injury to leaves or check in photosynthesis. He concluded that a temperature of 30°C should not be exceeded.

Evans (7) confirmed that within the propagating chamber it was difficult to separate the effects of light and temperature. He found that optimum rooting takes place within a temperature range of 27°-30°C. If, as the result of allowing extra light into the bins, the temperature rose to 32°C for lengthy periods the extent of rooting was considerably reduced.

In Costa Rica it was found that the maximum temperature should not be above 28° to 30°C for optimum rooting (1). In Suriname experiments conducted by Stahel (13) showed that a temperature range of 35° to 36°C "stimulated growth" and considerably reduced rooting, as compared with results obtained at a temperature below 30°C.

No specific mention is made in any of the literature reviewed on the minimum temperature limit for optimum rooting.

The influence of light intensity alone separated from the complicating effects of temperature was investigated, and Evans (7) concluded that light intensity divorced from the effects of temperature and humidity is not a crucial factor in the rooting of cacao, provided that intensity and photoperiod are within certain limits. For conditions when it is not possible to separate the effects of light and temperature an average of 12 to 14 percent of effective sunlight is considered optimum for closed bins, and 20 percent to 25 percent in open bins, with a continuous fine mist spray of water during daylight hours.

Previously Pyke (11) had suggested 1/4 to 1/8 relative illumination as the probable optimum for cacao cuttings.

Stahel (13) noted that on dark days in the rainy season in Suriname 10 percent insolation proved too low, and it was necessary, to make provision for varying the amount of light entering the bins in accordance with weather conditions.

In Costa Rica where light intensities reach values as high as 20,000 ft. candles a 75 percent shade is recommended (1).

Pyke (11) noted that the enormous leaf surface area of cacao necessitates an atmosphere of no saturation deficit, and this fact has not been questioned by other workers in the field.

Pyke (11) investigated a limited number of rooting media and obtained the best results with a course grained calcareous sand. He noted that it had the valuable property of being well drained and provided a poor nidus for bacterial and fungal growth.

The merits of different rooting media were studied extensively by Evans (7), who demonstrated that each rooting medium has its own optimal water requirements and that comparisons should be made on this basis.

Composted sawdust was found to be superior to the sand used by Pyke. Other media tried included vermiculite and slate wool; the former proved to be an excellent rooting medium with a watering schedule similar to sawdust, but it had a tendency to pack with usage. Slate wool was found inferior to vermiculite.

It was noted by Pyke (11) that access of oxygen to the base of the cutting was necessary for initiation and development of a wound callus in cacao, as respiration of these tissues is very active. The air-moisture relation at the base of the cutting was considered by Evans (7) to be the most important of all the external variables for successful rooting.

Pyke (11) considered that the volume of air in the propagating chamber could be an important factor in softwood propagation as it determines the amount of ventilation necessary to maintain a sufficiency of carbon dioxide for assimilation; and the humidity requirements limit ventilation.

The possibility of increasing the carbon dioxide content of the propagating chamber was tried by Stahel (13), who found that adding an extra 0.03 percent to the actual quantity of CO_2 already present in the air inhibited rooting by accelerating the maturity of the leaf. He, however, obtained an increase in rooting by periodic ventilation of the bins as opposed to bins which remain closed during the period of the experiment.

A period of hardening subsequent to rooting was found to be necessary. Pyke (11) stated that the best technique was to pot the cuttings as soon as they were rooted, place them in a closed chamber in the greenhouse for three to four weeks, then harden them off gradually by reducing the humidity in the chamber by raising the lid; and later place the plants in a sheltered part of the greenhouse before planting out.

Further work by Evans (7) modified the process by reducing the period in the bins to 12 days. He showed that two distinct phases are involved in the process, the first, and more important, involves the production of a root system adequate to supply the requirements of the shoot. The second involves acclimatizing the cutting from the more or less saturated atmosphere of the hardening chamber to the lower humidity of the outside atmosphere.

Another modification of the process was worked out by Burchardt and Jorgensen (3) for hardening in situ. Evans (7) found that this method was particularly suitable when sawdust formed the rooting medium.

B. Internal Factors

It has been established by Pyke (11) that for successful rooting, the cacao cutting must consist of soft or semi-soft wood material from a recently matured growth flush on which leaves are present. Particularly good results were obtained from vigorous flushes which had just reached maturity on two year old trees. Both short and long flushes (from six to nine inches in length) were used and it was noted that the latter rooted more readily.

The pioneer in the propagation of single-leaf cuttings was Stahel (13) who successfully rooted individual leaves with a small portion of the branch and an axillary bud, to provide the shoot. External requirements for rooting were the same as for stem cutting.

The part played by the green leaf in the rooting of cutting was investigated also by Evans (7), who concluded that the function of the leaf was to provide the cutting with carbohydrates and to a lesser extent soluble nitrogen compounds. There was no evidence that the leaf excersised a special formative effect which could not be replaced by major nutrients together with root-inducing hormones.

Previously Pyke (11) had noted that it was important to keep as many healthy leaves as possible on the cutting to conform with the principle of using actively photosynthesising material. In most of the experiments the larger leaves were trimmed back to about half their original area, and smaller leaves to two thirds. No evaluation on the effect of this practice was made. He suggested that the reduction of the assimilating surface was compensated for by the better presentation the trimmed leaves offer to the light.

He also found that artificially increasing the carbohydrate content by ringing, caused the cuttings drop their leaves to a greater extent and develop less roots than control cuttings, from similar but unringed shoots.

Evans (7) subsequently found that ringing had more effect than merely increasing the carbohydrate status and resulted in complicated changes in the shoot.

Stahel (11) tried to stimulate the growth of leaves by applying an atmosphere of ethylene gas (1:1000,000) and reported that stimulation of the leaf growth hinders the formation of roots. He concluded that it was necessary to use young leaves and to prevent the growth of the cutting from being stimulated, and thereby keep the leaves from becoming mature until the roots are formed.

Other factors affecting rooting were reported to be the age of the tree from which the cutting was taken, old trees producing cuttings which give low rooting. Shade of the parent tree also affected the rooting of cuttings, good success being achieved with material from medium shaded trees and little success with cuttings from trees under no shade or light shade. Evans (7) evaluated the effect of shade on nursery plants on the rooting of cuttings and found that the best results were obtained in the range 25 to 50 percent of light.

Evans investigated the effect of several root inducing hormones. He found the "quick dip" method convenient and the best treatment to be mixture a of equal parts of a-napthalene acetic acid and b-indolebutyric acid at a total concentration of 8-10 mgrs. per millilitre of 50 percent alcohol for stem cuttings, and half this concentration for single node cuttings.

This was not confirmed by Alvim and Duarte (2) who carried out several experiments comparing the effects of different formulations of root inducing substances on cacao cuttings. They found that the best aid to rooting was indolebutyric acid at 0.7 and 0.8 percent in 60 percent alcohol or talc. They recommended the powder mixture, 3:1 of talc and Phygon L or talc and SR-406 with 0.7 or 0.8 percent indolebutyric acid, as the best formulation.

The effect of the introduction of nutrients on the rooting of cuttings was investigated by Evans (7). He found that most of the substances selected, with the exception of sucrose, were ineffective alone but improved rooting when combined with others. Combinations of sucrose with mixtures of various amino acids, vitamins and manganese sulphate produced stronger and more abundant roots. The influence of an additional supply of nutrients was particularly marked in difficult to root clnes.

Observation on mineral deficiencies and their effect on the rooting of cuttings showed that in addition to nitrogen, the most frequent deficiency in nursery trees in the Caribbean areas was iron. In rare instances deficiencies of manganese, copper and magnesium may occur. The corrective treatment suggested for nursery material is liberal dressings of farm yard manure supplemented by small periodic applications of artificial fertilizer (1/4 lb. of sulphate of ammonia and muriate or sulphate of potash and two ounces superphosphate to each tree every two months). Trees deficient in iron respond rapidly to spraying with 1 percent iron sulphate, whilst copper and manganese deficiency are corrected with 0.5 percent manganese sulphate, and Bondeaux mixture respectively. It was shown that mineral deficient leaves deteriorate rapidly in the propagation process.

There is no mention in the literature reviewed on the positional effect of the cutting on the parent tree upon rooting, nor in evaluating the rooting potential of different fan branches (plagiotropic). Pyke (10) did compare fan and chupon (orthotropic) branches and reported that chupon branches were somewhat slower in rooting.

Experience with other crops indicates that these factors could affect rooting behaviour. Fiester (8) obtained significant variation in the natural rooting ability of cutting material taken from different portions in the orthotropic stem of Coffea arabica. The first three nodes counting from the apical tip gave the most satisfactory material for making cuttings for vegetative propagation.

Garner and Hatcher (9) experimented with three rootstock varieties, i.e., Myrobalan B plum (ready rooting), Brompton plum (moderate rooting) and Crab C Apple (shy rooting). For each variety, apical, middle and basal cuttings were used. It was reported inter alia: Layer cuttings were superior in rooting to their hedge counterparts, with a position gradient declining towards the shoot apex.

MATERIALS AND METHODS

The following materials and methods were used in the conduct of the experiments reported in this paper. In cases which are too specific to be included in these general descriptions, the details are recorded in the appropriate experiments.

Propagation Equipment

The equipment used was located in the propagation house at the Institute (6). It consisted of a series of concrete propagating bins of "Turrialba-3" type with bins of a surface area of 5.2 sq. ft. separated by cross walls.

Wooden trays with a surface area of 5.1 sq. ft. and 4.5 inches in depth were used for containing the rooting medium. The bottom of the tray was provided with drainage holes. Propagating bins of similar type but twice the surface area were also used.

The bins were covered with wooden sashes fitted with cotton cloth, and kept constantly wet by means of burlap wicks with one end in a water trough running the length of the battery of bins. The water level in the trough was maintained by adjusting the water flow through a faucet.

The bins used for the experimental area were situated under the slatted roof which allowed about 60 percent light. Removable slatted bin covers allowing 1/3 light were used at certain periods. The storage area consisting of concrete benches was also situated under the slatted roof. (Figs. 1 and 2).

Fig. 1. Internal view of propagation house showing arrangements of propagating bins, watering system, equipment for hardening and removable shade covers.

Fig. 2. Internal view of propagation house showing storage area.

Preparation of Material

The rooting medium of sawdust was placed in the cutting tray and prepared in advance. On the day previous to setting the medium was wetted to its proper moisture content. The pots used were made of sisal-kraft paper, six-ply for the normal size pots (5.5" x 5" x 5") and three-ply for the medium (4" x 4" x 5") and small sized pots (3" x 3" x 5"). These were prepared by filling the pot with soil around a glass bottle, withdrawing the bottle to leave a well, two and one half inches in diameter and extending the depth of the pot. The rooting medium of sawdust was placed in this space and lightly tamped. The small sized pots were filled with sawdust only (Fig. 6).

The plots were either whole bins or in the case where one bin was used for more than one treatment, the plots were outlined with string. Each plot was marked with wooden plot labels, in addition plans were made of the experimental layouts.

Preparation of Cuttings

The source of plant material for these experiments was a three year old clonal planting on the Institute's farm, in a field referred to as Turrialba planting No.1. The plants were grown under shade, comprised of Erythrina sp. and bananas, estimated to allow 40 percent to 60 percent effective sunlight.

Field collections of cuttings for these experiments were made in the morning between 7:00 a.m. and 9:00 a.m. immediately prior to the setting of the cuttings. Recently matured growth flushes with the upper side of the stem, brown, and underside still green, were servered with pruning shears, and shaded in the field until their removal to the greenhouse. Upon arrival in the greenhouse the material was watered and placed under wet cloth.

Individual cuttings were made from the previously collected plant material. Two types of cutting were prepared, i.e., six node and four node. (Figs. 3 and 4). The former consisted of the top six nodes of the flush whilst the latter were the contiguous apical and basal portions of the terminal eight nodes of the flush. The apical portion including the terminal node. In preparing the cuttings, all cuts were made with a sharp nursery man's knife at a slight oblique angle, just below a node. Root inducing hormone consisting of a powder mixture of 3:1 of talc and Phygon XL with 0.8 percent indolebutyric acid was applied to the cut end immediately prior to setting (6).

Care of cuttings after setting consisted of a watering and shading schedule depending on the weather. The cuttings were watered a maximum of three times per day; at 10:00 a.m., 1:00 p.m. and 3:00 p.m. on sunny days; to no watering on rainy days. A watering consisted of a light sprinkling, the main object being the wetting of the leaves to aid in maintaining the humidity in the bins and to reduce transpiration in periods of bright light and increased temperature. The removable slatted bin covers provided additional shade over the bins between the hours of 10:00 a.m. and 3:00 p.m. on bright sunny days, but were not used in dull or rainy periods. Fallen leaves were removed as occasion demanded.

Fig. 3. A six leaf cutting

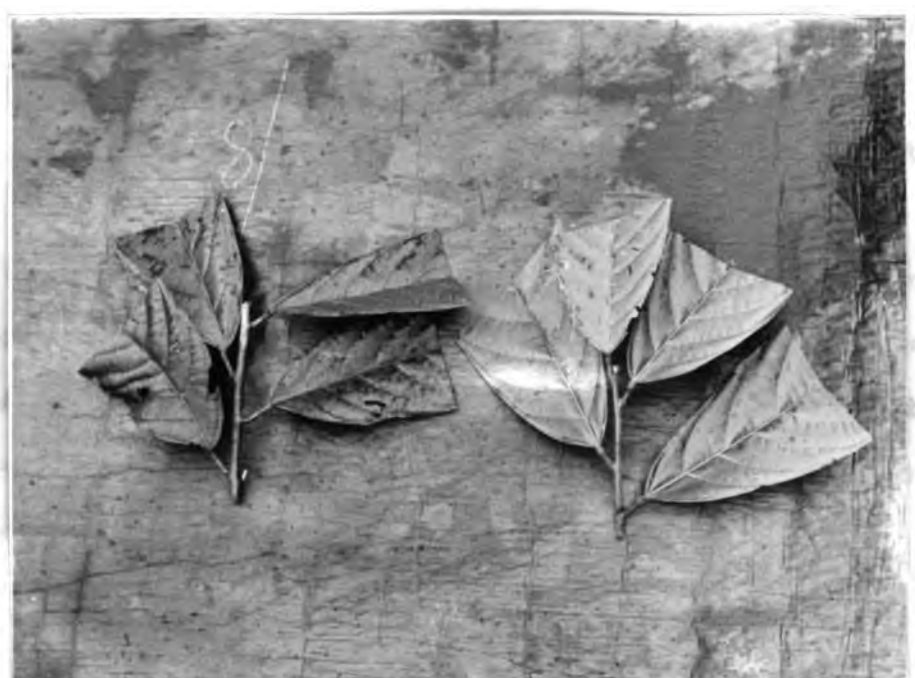


Fig. 4. A basal and an apical four leaf cutting

Collection of Data

On completion of the experimental period the following data were taken and the procedure for handling is set out below:

Number of cuttings alive - counted at the end of the experiment, for each plot.

Number of cuttings rooted - was determined after removing all of the cuttings in a plot.

Number of primary roots - counted for each plot after severing the roots from each cutting with a sharp scissors.

Fresh weight of the roots - obtained by weighing the severed roots from each plot; the balance used was accurate to 0.1 grms.

Number of leaves - determined by counting the number of leaves remaining on; (a) the rooted cutting and (b) non-rooted live cuttings in each plot.

Cuttings were not classified as live or rooted without a minimum of one healthy leaf.

Number of plants produced - was determined by the number of plants alive 10 days after completion of the hardening period.

The indices used to express rooting efficiency (RE) and propagation efficiency (PE), were those recommended at the V Meeting of the Inter-American Technical Cacao Committee (10). (RE) is the number of cuttings rooted per 100 set in the propagating bins; PE is the number of plants produced per 100 cutting set in the propagating bins.

Analysis of Data

The data were analysed statistically by analysis of variance and the minimum significant differences were calculated at the 5% level. The data recorded as percentages were transformed by the angular or arc sine transformation before analysis (12).

EXPERIMENTAL RESULTS

Experiments I and Ia. - Evaluation of the pot-rooting technique

The increased efficiency of the pot-rooting technique is attributed to reduction in losses by the elimination of transplanting since there is no check in growth or possibility of damage to roots as the latter grow into the soil upon development. At the same time, two disadvantages have become apparent: first, it is not possible to identify the well rooted cutting before transplanting as in the standard method. Consequently poorly rooted cuttings enter the storage sheds as healthy plants and eventualy die; secondly, the number of cuttings set per bin is less than for the standard method because of the space occupied by the pots and soil.

A solution to these problems would further increase propagation efficiency and accordingly an experiment was designed with the following objectives:

(a) to compare under controlled conditions, the standard method as used at the Institute with the pot-rooting technique.

(b) to find a means of increasing the number of cuttings per bin with the pot-rooting technique to the same level as for the standard method, and

(c) to find a means of identifying the well rooted cuttings.

Treatments used were four in number; as described in Materials and Methods.

1. Standard closed bin method as carried out at the Institute.

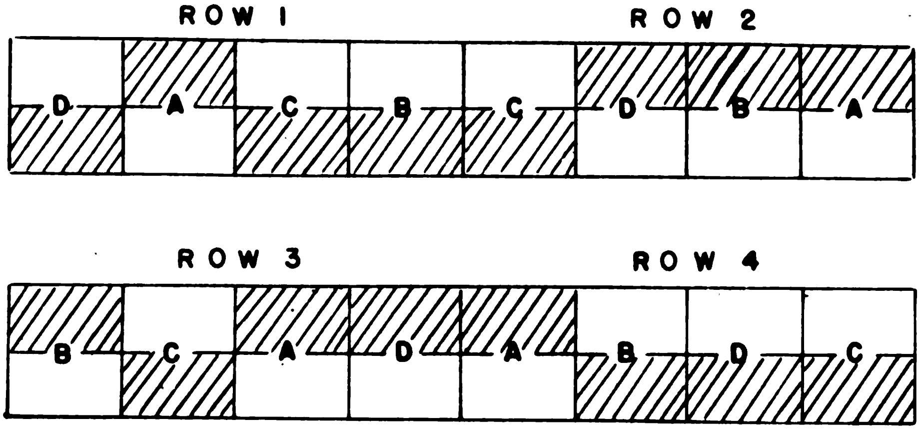
2. Propagating in normal size pots (5.5" x 5" x 5") as used for potting after removal from the rooting bins in 1.
3. Propagating in medium size pots (4" x 4" x 5").
4. Propagating in small size pots (3" x 3" x 4").

The experimental area was sixteen propagating bins in two rows of eight within a 4 x 4 latin square design, (Figs. 5 and 6), each bin comprising a plot. Provision was made for repeating the experiment as it was only possible to install four replications with the equipment available.

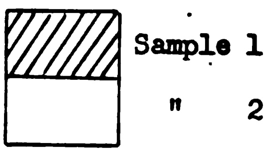
Experiment I. was set on February 14; hardening which was carried out in situ, was commenced on March 23 at the end of the rooting period, and ended on March 30th. In hardening the bin covers were raised two inches for the first two days, four inehes for the next two days, eight inches for the following two days and fifteen inches for the next two days.

On completion of the hardening period the plots were divided into two equal parts by random choice. Rooted cuttings from the half plots designated for storage were treated as follows. In the case of the standard treatment, the rooted cutting were potted out in accordance with the normal practice of the propagating house (6). Live cuttings in the medium and small size pots were transplanted in their respective pots, into normal size pots. Live cuttings in the treatment for normal size pots were left intact. All potted plants were removed to the storage area and set out in plots in the same randomization as they occupied in the bins.

EXPERIMENT I.

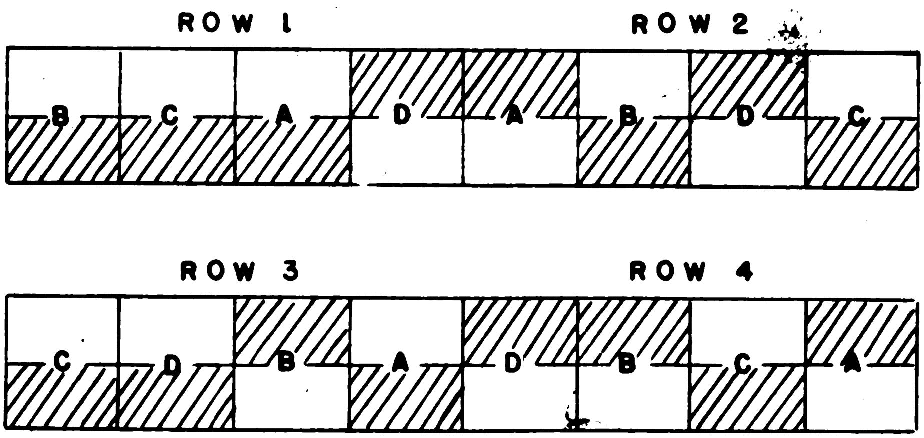


TREATMENTS

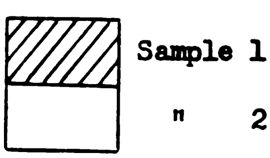


A = SMALL POTS = 30 CUTTINGS
B = NORMAL POTS = 20 CUTTINGS
C = MEDIUM POTS = 30 CUTTINGS
D = STANDARD = 30 CUTTINGS

EXPERIMENT Ia.



TREATMENTS



A = NORMAL POTS = 16 CUTTINGS
B = STANDARD = 24 CUTTINGS
C = MEDIUM POTS = 24 CUTTINGS
D = SMALL POTS = 24 CUTTINGS

FIG. 5 EXPERIMENTAL DESIGNS USED IN EXPERIMENTS I & Ia

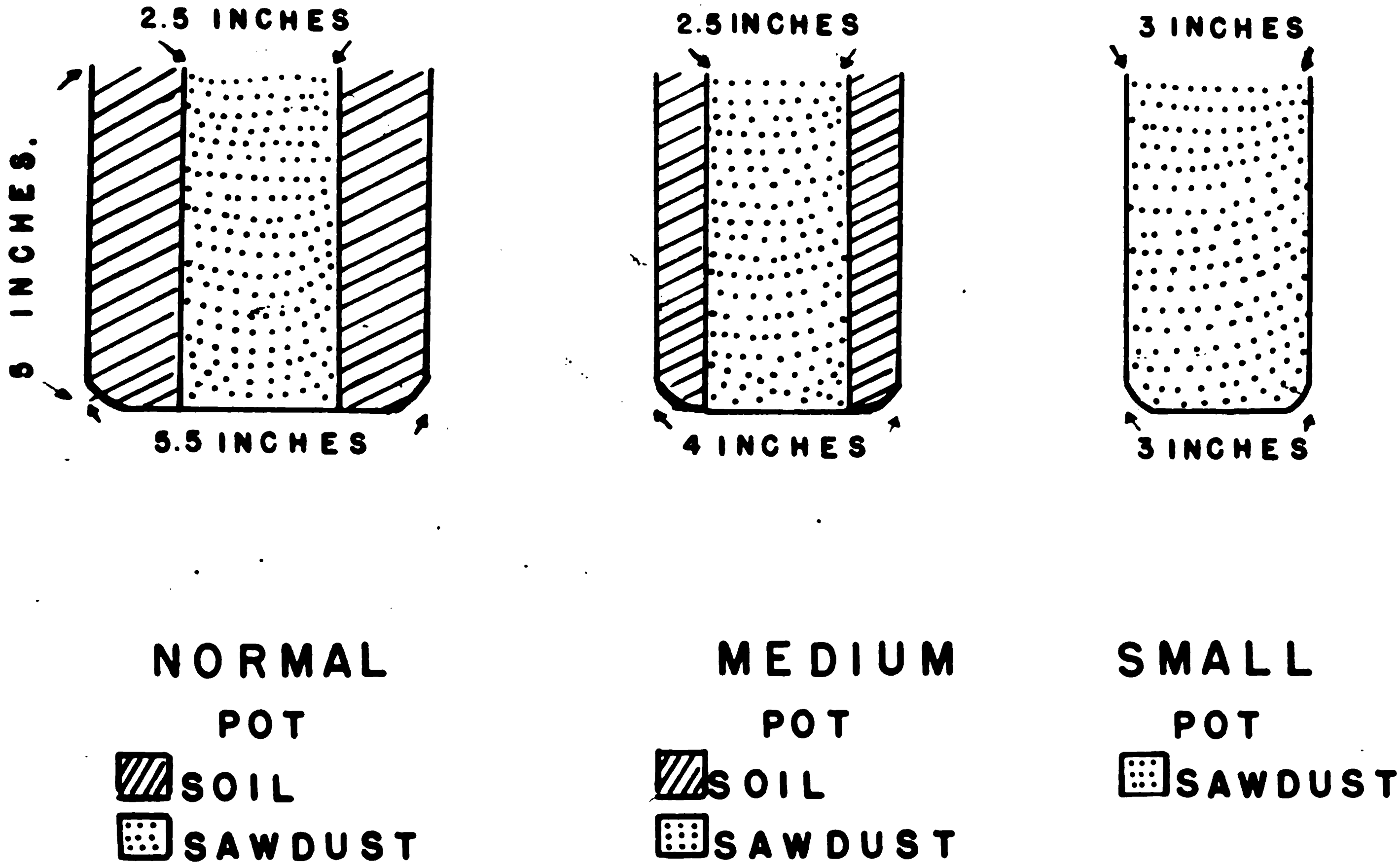


FIG.6.VERTICAL CROSS SECTION OF POTS USED IN EXPERIMENTS I & Ia

The cuttings from the other half plots were removed by slitting the pots with a sharp knife; the rooted cuttings were carefully removed, and the roots were immersed in water to remove sawdust and soil. Data were collected as described in Materials and Methods. It was considered more convenient to discuss the results of the two experiments together.

Certain modifications were introduced into the "repeat" experiment. It was observed that the normal trays used for containing the rooting medium, although provided with drainage holes, did not prevent excess watering of the pots with soil, because of insufficient drainage. In addition the cuttings nearest the back wall of the propagating bin were subjected to water drip which accentuated the excessive moisture conditions. To overcome these defects the tray which served as a container for the pots was redesigned with a slatted bottom, and the plot size reduced by 20 percent to eliminate the back row of cuttings. Thus the number of cuttings per plot was twenty-four for treatments for the standard and two smaller size pots, and sixteen for the normal size pots.

Experiment Ia, was set on April 26, hardening was commenced on May 21 after completion of rooting, and ended on 8th June. The procedure used was the same as described for the first experiment. The data relating to the cuttings which were examined after the hardening period are presented in Tables 1 and 2.

The experiments gave no evidence of significant differences among treatments (Appendix 1, 2). A large proportion of the cuttings remained alive in both experiments, but the variation between treatments was

Table 1. Percent cuttings alive and rooted, average number and weight of roots, and average number of leaves per cutting in Experiment I.

Treatment	Number of cuttings set	Percent cuttings alive	Percent cuttings rooted	Av. No. of roots per cutting	Av. weight of roots per cutting (gms.)	Av. No. of leaves per cutting
Standard	60	97	72	6.0	1.2	3.6
Normal pot	40	100	70	5.6	1.3	3.7
Medium pot	60	97	73	6.3	1.0	3.5
Small pot	60	98	76	6.9	1.3	3.0

Table 2. Percent cuttings alive and rooted average number and weight of roots and average number of leaves per cutting in Experiment Ia.

Treatment	Number of cuttings set	Percent cutting alive	Percent cuttings rooted	Av. No. of roots per cuttings	Av. weight of roots per cutting (gms.)	Av. No. of leaves per cutting
Standard	48	92	65	8.0	1.7	2.4
Normal pot	32	100	75	8.0	1.8	3.8
Medium pot	48	81	60	6.0	1.4	2.5
Small pot	48	83	44	6.0	1.5	3.0

only three percent in Experiment I as compared with 17 percent in Experiment Ia. There was a somewhat higher level of rooting and more uniformity among treatments in Experiment I; six percent variation between the highest and lowest as compared with 21 percent in Experiment Ia. The average number of roots shows little variation among treatment or between experiments.

The average number of leaves per cutting varied from 3.0 to 3.7 in Experiment I and 2.4 to 3.0 in Experiment Ia.; showing a loss of 2.3 to 3.0 leaves per cutting in Experiment I and 3.0 to 3.6 in Experiment Ia.

An interesting feature of both Experiments is the number of live cuttings which did not root in the test period : a range of 22 to 30 percent for the treatments in Experiment I and 21 to 34 percent in Experiment Ia.

During the course of Experiment Ia. there were periods of heavy and continuous rain; meterological records of the Institute show precipitation of 22.92 inches as compared with 5.36 inches for the duration of Experiment I; this resulted in excessive watering as the cloth covers of the propagating bins could provide no protection in this respect.

Data relating to the rooted cuttings which were potted and placed in the storage area are in Tables 3 and 4.

The experiments gave no evidence of significant differences among treatments.

The data indicate that the variation in percent plants produced between the highest and lowest treatments was 23 percent in Experiment I and 25 percent in Experiment Ia.

Table 3. Number and percent plants produced in Experiment I.

Treatment	Number of cuttings set	No. of plants at end of hardening	Number of plants produced	Percent plants produced (PE)
Standard	60	42	35	58
Normal pot	40	40	23	57
Medium	60	53	31	50
Small pot	60	58	44	73

Table 4. Number and percent plants produced in Experiment Ia.

Treatment	Number of cuttings set	No. of plants at end of hardening	Number of plants produced	Percent plants produced (PE)
Standard	48	40	36	75
Normal pot	32	26	14	46
Medium pot	48	43	32	67
Small pot	48	29	24	50

In considering the actual number of plants produced, the normal pot, treatment resulted in considerably fewer plants than the other treatments.

The combined data for the two experiments are summarized in Table 5.

Table 5. Number and percent plants produced in Experiments I and Experiment Ia, combined.

Treatment	Number of cuttings set	No. of plants at end of hardening	Number of plants produced	Percent plants produced (PE)
Standard	108	82	71	66
Normal pot	72	66	47	51
Medium pot	108	96	63	58
Small pot	108	87	68	61

On the basis of actual plants produced, the normal pot treatment gave 33 percent fewer than the standard, whilst on the Propagation Efficiency (PE) basis the reduction was only 15 percent.

The number of cuttings originally set for Normal pot was 30 percent less than for the other treatments. (Figs. 7 and 7a.)

The percentage loss during storage in the pot treatments is influenced by not being able to identify the poorly rooted plants. Special observations relating to this problem were carried out and the data are presented in Table 6.

Fig. 7. Interior view of a propagating bin showing cuttings set in the standard method.

Fig. 7a. Interior view of a propagating bin showing cuttings set in. the pot rooting method (normal pot).

Table 6. Percent cuttings rooted and per cent pots showing root penetration in medium and small pots.

	Experiment I		Experiment Ia.	
Treatment	Percent cuttings rooted	Percent pots with root penetration	Percent cuttings rooted	Percent pots with roots penetration
Medium	73	50	50	40
Small pot	76	31	44	25

These results show that with the type of pot used, root penetration is not a sure means of identifying all the well rooted plants. In both experiments the medium pot treatment showed a higher percent of pots with root penetration probably by reason of the softening of the pot through contact with the wet soil.

In Experiment Ia. the small sized-pots which showed no root penetration were slit with a sharp knife and the roots examined. This did not interfere with the subsequent potting of the rooted cutting into a normal size pot.

Discussion of Experiment I and Ia.

The pot rooting method has not proved superior to the standard method, when compared on the basis of propagation efficiency (PE). The higher efficiency of the pot-rooting method in commercial practice is ascribed to the elimination of transplanting and the earlier exploration of the soil by the roots. At the end of the hardening period as shown by the data in Tables 1 and 2 there was no evidence of greater root development as expressed by number and weight of roots, in the treatments using soil than in the other treatments.

It should be noted, however, that in both experiments the air moisture relationship of the soil was sub-optimal and could have restricted root development in the soil to a greater extent than in the rooting medium. The volume of rooting medium per cutting was in a ratio of 1:2:4.5 for the normal and medium pots, small pots, and standard respectively. The treatments with a smaller volume of rooting medium would more likely be adversely affected by excess watering.

When the pot treatments with and without soil are compared on the basis of root development, there was no apparent advantage in using soil. Again however, the unsuitable moisture conditions obtaining during the period of the experiments could have retarded the growth of roots in the soil.

On the basis of the economy in use of propagating space, the number of cuttings which could be set in the treatments with the normal pot was 33 percent less than with the other treatments. The production of plants by the normal pot treatment in the two experiments combined, was 33 percent less than the standard and 30 percent and 26 percent less than the small and medium pot treatments (Table 5). Thus, there was no apparent advantage in using more propagating space, as the normal pot treatment was not more efficient in converting a cutting into a plant.

The one compensating factor in favour of the use of normal size pots is the possibility of not having to repot in the course of the propagation process. On the other hand, if repotting is necessary, as it now is in normal commercial cacao cuttage then it would be advantageous, both from the viewpoint of efficient use of propagating space and saving in cost to set the cutting in a smaller size pot and transplant into a larger pot at the end of the hardening period. This would obviate the need of bare rooting as the cutting can be planted with the pot. Thus more economical use of propagating space can be obtained by using smaller size pots.

The other disadvantage of the pot-rooting method, i.e., identifying of rooted cuttings has been overcome. It has been shown that roots of cacao cuttings will penetrate pots made of 3-ply sisalkraft paper. At the same time under the conditions of the experiments, it was found that root penetration alone was not a sure means of identifying all cuttings which had rooted successfully. Thus 40 to 44 percent of rooted cuttings showed root penetration in the small pots and 68 to 80 percent in the medium pots. By slitting the small pots which showed no root emergence, it was possible to examine the roots, and at the same time avoid having to bare-root the cutting, as subsequent potting of the cutting including the pot was easily accomplished.

A problem in large scale cacao cuttage by the closed bin system is the volume of rooting medium which is necessary as well as its periodic removal and replacement in the bins. When sawdust is used as the rooting medium it is replaced every three to four months. In the pot-rooting method each pot contains its own rooting medium, thus there is no need for periodic replacement in the bins.

As to the relative quantities of rooting medium required; the cuttings set in the pots with soil used 24 cubic inches of rooting medium as compared with 45 cubic inches for the pots without soil and 109 subic inches for the standard. On the other hand the latter could be used for two to three settings which would reduce the required volume per cutting to 36 to 54 cubic inches approximately the same as for the pot treatment with no soil.

When the rooting medium of sawdust has passed beyond a certain state of decomposition, it becomes a medium for a host of fungi and nematodes, which can be associated with disease problems in the propagating bins (4). The use of the pot-rooting method would to a large extent dispense with this problem.

Other features of the data which should be noted and which merit discussion relate to non-rooted live cuttings, and number of leaves at the commencement and end of the experiments. The relatively large proportion of non-rooted live cutting after the ample rooting period viz. 22 to 30 percent in Experiment I and 21 to 39 percent in Experiment Ia., is somewhat difficult to explain, the more so as no comparative data is available either on an experimental or commercial basis.

The number of leaves set per cutting was six, while the number of leaves remaining at the end of the hardening period varied among the different treatment from 3.0 to 3.7 in Experiment I and 2.4 to 3.0 in Experiment Ia. In both cases the highest number of leaves remained on cutting set in the normal pot. This was probably the result of having more light due to wider spacing of the cuttings.

No previous quantitative evaluation of leaf loss in cacao cuttage has been recorded. It has been shown that the presence of leaves is necessary for rooting, again it has been shown that using a single-node, a single leaf provides sufficient assimilating surface for root formation.

It has been reported that the lower limit of leaf surface necessary for rooting is between 10 and 15 percent of the original area. It was also found that the minimal leaf area required for rooting varied with the environmental factors particularly light intensity; and was also determined by the weight of stem tissue supplied by the given leaf area (7). There was no indication however, of the original leaf area of the cuttings used, and no evaluation of the optimum leaf stem ratio of cuttings.

It would appear from these experiments that loss of leaves of the order of 27 to 60 percent did not adversely affect rooting behaviour.

The practical implications could be of importance in determining the optimum number of leaves per cutting, and size of cutting. One method of increasing the yield of cuttings gardens is to reduce the size of the cutting.

Conclusions of Experiment I and Ia.

1. The propagating equipment described did not provide satisfactory control of the air moisture relationship of the rooting medium, and of the soil.
2. Under the conditions of the experiment the pot rooting technique

was not more effecient than the standard method in converting a cutting into a plant.

3. Medium and small sized pots resulted in better economy in the use of propagating space than the normal size pots.
4. There was no apparent advantage in using soil surrounding the rooting medium.
5. Root penetration of the pot did not provide a sure means of identifying adequately rooted cutting. A practical method using this principle was however worked out by slitting the small pots for root examination when no roots were visible.
6. Further research on the problem of non-rooted live cuttings and the leaf requirements in cacao cuttage are indicated.

Experiment II. - The effect on rooting behaviour of the source and position of the cutting on the tree.

As far as the writer is aware there is no record of any previous investigational work carried out on the rooting behaviour of cacao cuttings derived from different branches and from different positions within the branch. For the purpose of this experiment, only fan branches (plagiotropic) were considered as these are normally used for providing cutting material in commercial cacao cuttage. An examination of the clonal trees comprising the source of the cutting material used in this experiment suggested a convenient classification of branches to consist of: primary branches those which formed part of the original growth of the tree; upper secondary branches, those arising from primary branches and of not more than half the diameter of the primery; and, lower secondary, of more mature growth than the upper secondary and more than half the diameter of the primary. This classification is illustrated in Fig. 8.

This experiment was designed to compare the rooting behaviour of apical and basal cuttings obtained from primary branches, upper secondary branches and lower secondary branches. Three different clones were used, viz. UFCo. 221, 667 and 613 already reported to be "ready", "moderate" and "shy" rooting, respectively.

The experimental design was a split plot arranged in a 3 x 3 x 2 factorial using two replications (Fig. 9). The branches were considered major treatments and the clones and apical and basal positions secondary treatments.

Experiment II was set on April 28th and on June 8th, after 40 days in the propagating bin, the cuttings were removed and data collected as described in Materials and Methods.

During the course of this experiment, 23 inches of rain was recorded at the Institute meteorological station; this resulted in excessive watering of the rooting medium which was reflected in unfavourable air-moisture relations in the medium and which casued a veinal yellowing of the leaves followed by abscission. The condition was more severe in clone 613 than the other two clones, and by the 28th day, all the cuttings of clone 613 had died. Data for the experiment was therefore restricted to the cuttings of clone 667 and 221.

The data pertaining to number of cuttings alive and rooted are

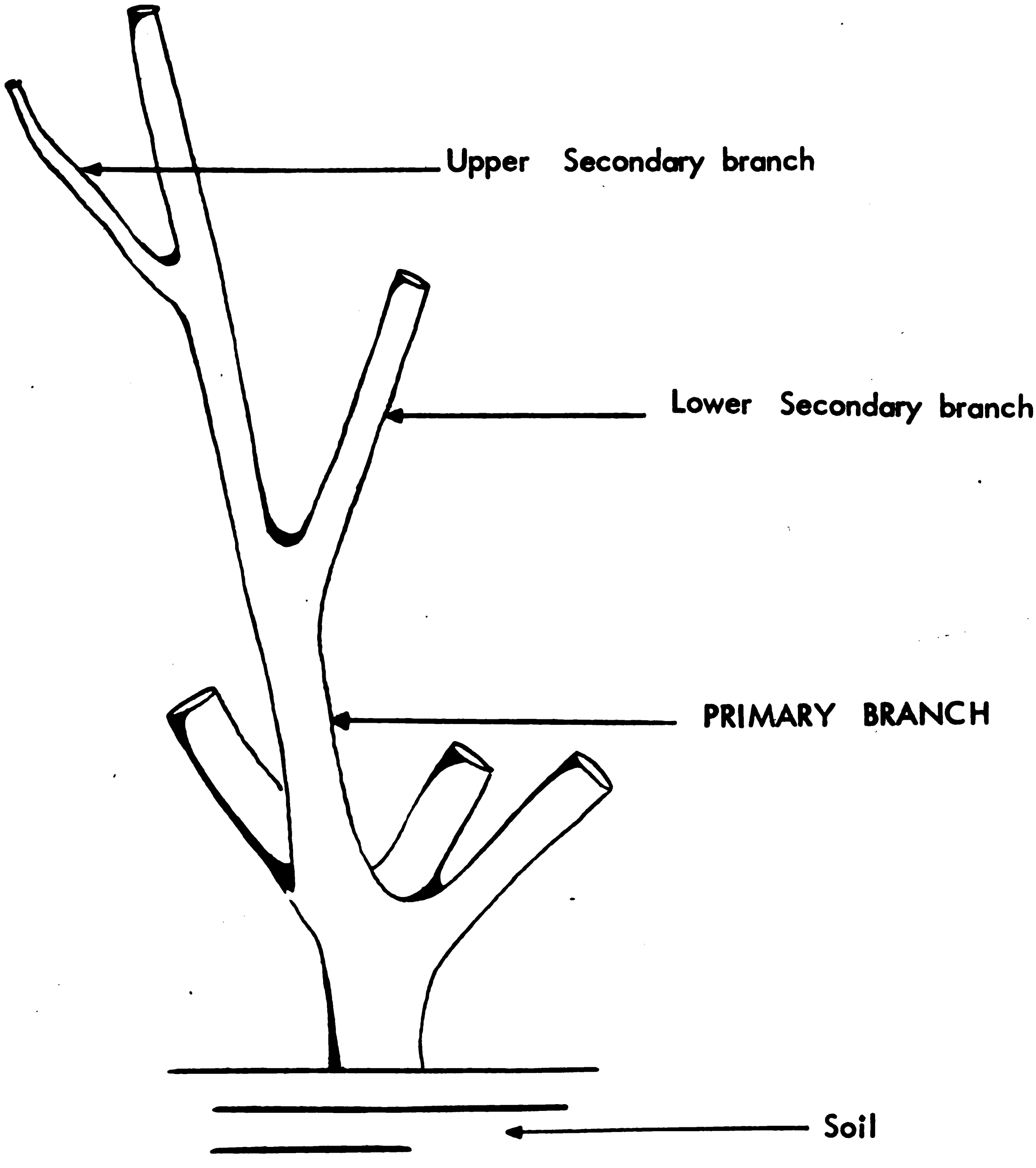


Fig. 8. Arrangement of branches on a

EXPERIMENT II

CLONE 677			CLONE 221			CLONE 613			CLONE 613			CLONE 221			CLONE 677		
A	(b) C	B	B	(a) A	C	A	(a) B	C	C	(b) A	B	A	(b) C	B	B	(a) A	C
A	(a) B	C	C	(b) B	A	C	(b) A	B	B	(a) C	A	C	(a) A	B	A	(b) C	B

MAIN PLOT = 30 CUTTINGS

SUB. PLOT = 15 CUTTINGS

SUB. SUB. PLOT = 5 CUTTINGS

EXPERIMENT IIa

CLONE 221

Aa	Bb	Cb	Bb	Cb	Ca	Cb	Ab	Ba	Ab	Ba	Aa
Ba	Ca	Ab	Aa	Ba	Ab	Aa	Bb	Ca	Ca	Bb	Cb

PLOT = 5 CUTTINGS

LEGEND

A = PRIMARY BRANCH CUTTINGS

B = UPPER SECONDARY BRANCH CUTTINGS

C = LOWER SECONDARY BRANCH CUTTINGS

a = APICAL CUTTINGS

b = BASAL CUTTINGS

FIG. 9 EXPERIMENTAL DESIGNS USED IN EXPERIMENTS II & IIa set out in Tables 7 and 8.

Table 7. Number of cuttings alive for branches, position, and clone in Experiment II

Clone & Position		No. of cuttings set	Branches Primary	Upper Secondary	Lower Secondary	Total Position per clone	Clone
677	Apical	30	8	9	8	25	51
	Basal	30	10	9	7	26	
221	Apical	30	7	7	9	23	43
	Basal	30	6	6	8	20	
Total Branches		120	31	31	32		
Total Position:							
	Apical	60	48				
	Basal	60	46				

Table 8. Number of cuttings rooted for branches, position, and clone in Experiment II.

Clone & Position		No. of cuttings set	Branches Primary	Upper Secondary	Lower Secondary	Total Position per clone	Clone
677	Apical	30	5	3	5	13	32
	Basal	30	8	6	5	19	
221	Apical	30	4	5	4	13	30
	Basal	30	6	5	6	17	
Total Branches		120	23	19	20		
Total Position:							
	Apical	60	26				
	Basal	60	36				

There was no evidence of significant differences among treatments. (Appendix 3). At the same time it should be noted that the RE of basal cuttings was 60 as compared with 43 for apical. The difference between the RE among branches was 10 and between clones three.

The percent cuttings alive at the end of the experiment showed a range of 77 to 80 percent among branches; 72 to 85 percent between clones; and 77 to 80 between apical and basal positions.

The proportion of live cuttingswhich did not root was 40 percent of the apical and 17 per cent of the basal; 20 to 30 percent among branches; and 32 percent for clone 677 as compared with 22 percent for clone 221.

In tables 9 and 10 are set out the data pertaining to the average number and weight of roots per cuttings.

Table 9. Average number of roots per cutting for branches, position and clone in Experiment II.

Clone &	Position	Branches			Total	
		Primary	Upper secondary	Lower secondary	Position per clone	Clone
677	Apical	5.5	4.7	4.6	4.9	6.9
	Basal	8.0	9.2	9.1	8.8	
221	Apical	4.6	4.2	4.6	4.6	5.6
	Basal	5.6	6.7	7.6	6.6	
Average	Branches	6.0	6.3	6.5		
Average	Position:					
	Apical	4.8				
	Basal	7.7				

Table 10. Average weight (gms) of roots per cutting for branches, position and clone in Experiment II

Clone & Position		Branches: Primary	Branches: Upper secondary	Branches: Lower secondary	Total: Position per clone	Total: Clone
677	Apical	1.0	0.9	0.7	0.9	1.4
	Basal	1.5	2.0	2.1	1.8	
221	Apical	0.9	0.7	0.7	0.8	1.0
	Basal	1.0	1.0	1.6	1.2	
Average Branches		1.2	1.1	1.4		
Average Position:	Apical	0.8				
	Basal	1.5				

There was no evidence of significant differences among treatments (Appendix 3). It should be noted, however, that the number and weight of roots for basal cuttings was 47 percent higher than for apical cuttings. Similar data for cuttings from the different types of branches showed little or no variation. Clone 677 had 19 percent more roots per cutting and the roots weighed 29 percent more than those of clone 221.

The data contained in Tables 7, 8, 9, and 10 in set out in diagrammatic form in Fig. 10.

In Tables 11 and 12 are presented the data on leaves per rooted and non-rooted live cutting at the end of the experiment.

Table 11. Average number of leaves per rooted cutting for branches, position and clone in Experiment II.

Clone & Position		Branches: Primary	Branches: Upper secondary	Branches: Lower secondary	Total: Position per clone	Total: Clone
677	Apical	2.1	3.0	3.6	3.0	2.7
	Basal	2.2	2.3	3.6	2.6	
221	Apical	2.2	3.2	2.7	2.7	2.6
	Basal	2.3	1.7	3.1	2.4	
Average Branches		2.2	2.5	3.3		
Average Position:						
	Apical	2.6				
	Basal	2.5				

Table 12. Average number of leaves per non-rooted live cutting for branches, position and clone in Experiment II

Clone & Position		Branches: Primary	Branches: Upper secondary	Branches: Lower secondary	Total: Position per clone	Total: Clone
677	Apical	3.3	2.2	2.4	2.7	2.2
	Basal	1.0	1.7	1.5	1.4	
221	Apical	2.0	1.7	1.5	1.7	1.5
	Basal	-	1.0	1.0	1.3	
Average Branches		2.1	1.6	1.6		
Average Position:						
	Apical	2.2				
	Basal	1.4				

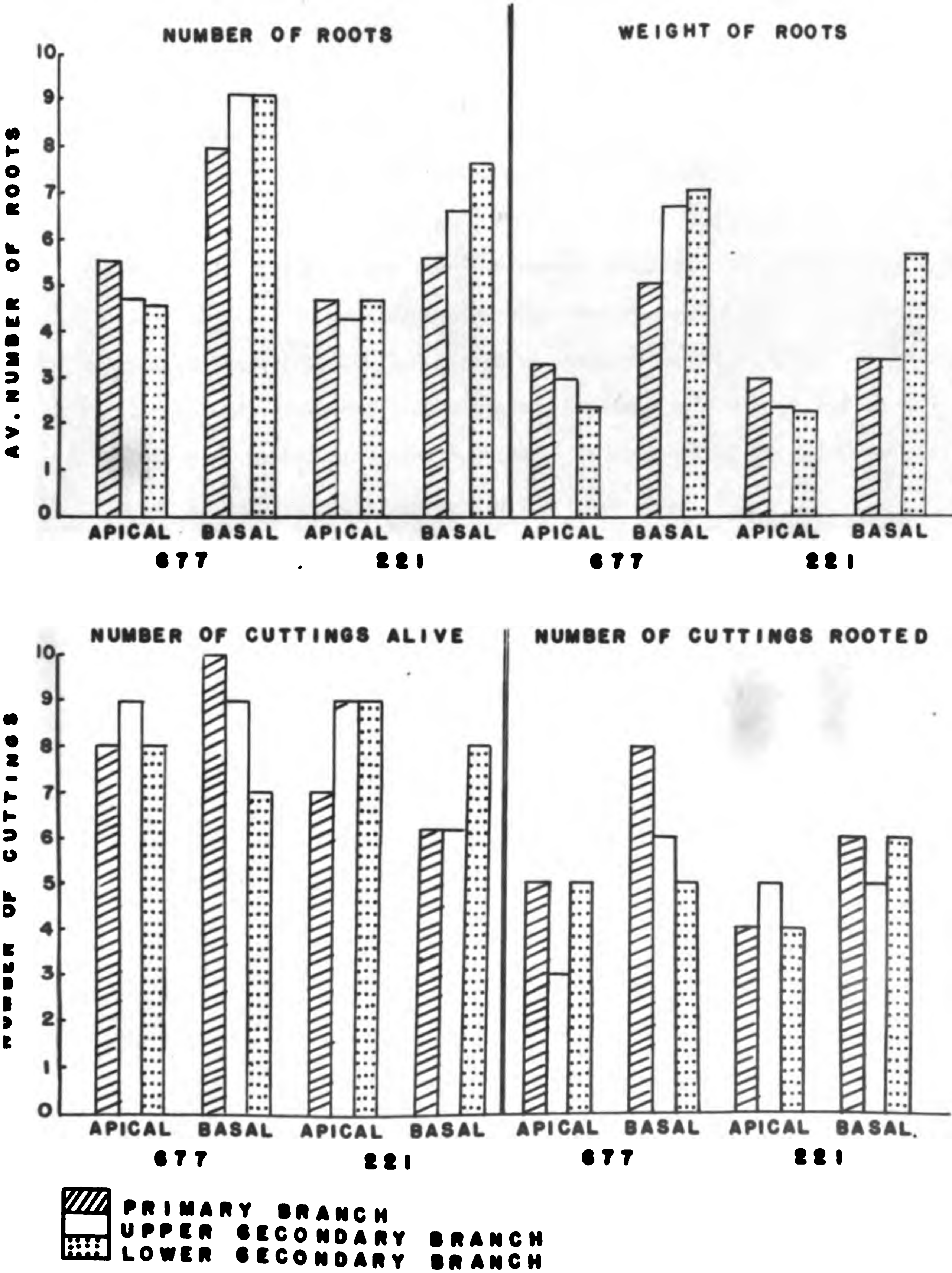


FIG. 10. NUMBER OF CUTTINGS ALIVE, NUMBER OF CUTTING ROOTED, AVERAGE NUMBER OF ROOTS PER CUTTING AND AVERAGE WEIGHT OF ROOTS PER CUTTING, FOR BRANCHES, POSITION AND CLONE IN EXPERIMENT II. DATA ARE IN TABLES 7,8,9,10.

The data indicate that the number of leaves remaining on the rooted cuttings showed little variation irrespective of the source of the cuttings except those derived from lower secondary branches, which retained more leaves than the other treatments; with the non-rooted cuttings, however, basal cuttings retained 1.4 leaves as compared with 2.2 leaves on the apical cuttings. Cuttings from different branches varied from 1.6 to 2.1 in the average number of leaves retained. Cuttings of clone 677 retained 2.2 leaves as compared with 1.6 leaves for clone 221.

Experiment IIa. - The effect on rooting behaviour of the source and position of the cutting on the tree.

Because of the reduction in the precision of Experiment II by the loss of the cuttings of one clone, it was decided to carry out an additional experiment using a different layout with clone 221.

The experimental design used was 4 randomized blocks. (Fig. 9). The bins were provided with glass frames covered with cloth in place of the cloth frames used previously. The experiment was set on May 29th and completed on June 27th after 29 days in the propagating bins. Data were collected as described in Materials and Methods.

The results from Block 4 were not used in the experiment due to a large number of deaths and non-rooted cuttings.

In Table 13 is set out the data pertaining to the number od cuttings alive, cuttings rooted, and average number of roots per cutting.

Table 13. Number of cutting alive, cuttings rooted, and average number of roots per cutting for branches, and position in Experiment IIa.

Treatment		Number of cuttings set	Number of cuttings alive	Number of cuttings rooted	Av. No. of roots per cutting
Primary	- Apical	15	10	6	4.0
Primary	- Basal	15	15	7	4.4
Upper secondary	- Apical	15	11	5	2.8
Upper secondary	- Basal	15	12	8	5.7
Lower secondary	- Apical	15	13	4	4.0
Lower secondary	- Basal	15	11	7	4.0
Total Branches					
Primary		30	25	13	4.2
Upper secondary		30	23	13	4.5
Lower secondary		30	24	11	4.0
Total Position					
	Apical	45	34	15	3.6
	Basal	45	38	22	4.8

The experiment gave no evidence of significant differences among treatments (Appendix 4). In assessing the data, it should be noted that the experiment was terminated before normal root development had been completed.

The data shows that 85 percent of the basal and 75 percent of the apical cuttings set, were alive at the end of the experiment.

Of the cuttings remaining alive, 56 percent of the apical, and 42 percent of the basal were not rooted.

Live cuttings from the different types of branches were 83, 76, and 80 perdent of the cuttings set, of which 48, 55 and 45 percent were not rooted.

The RE of the cuttings shows a value of 33 for apical as compared with 49 for basal; Primary branches, 43; upper secondary, 43; and lower secondary, 36.

The average number of root on cuttings from the different branches showed little variation; Basal cuttings produced 25 percent more roots than apical.

In Table 14 is set out the average number of leaves per rooted and non-rroted cutting at the commencement and end of the experiment.

Table 14. Average number of leaves per rooted and non-rooted live cutting for branches, and position in Experiment IIa.

Treatment		Average No. of leaves per root cutting	Average No. of leaves per non-rooted live cutting
Primary	- Apical	3.1	3.2
Primary	- Basal	3.3	2.1
Upper Sec.	- Apical	3.0	1.7
Upper Sec.	- Basal	3.1	2.2
Lower Sec.	- Apical	3.2	1.8
Lower Sec.	- Basal	2.9	3.0
Average Branches			
Primary		3.2	2.5
Upper secondary		3.0	1.9
Lower secondary		3.0	1.5
Average Position			
Apical		3.1	1.6
Basal		3.1	2.4

The average number of leaves per rooted cutting from the different types of branches and for apical and basal cuttings was remarkably uniform, having between 3.0 and 3.2 leaves. The number of leaves on the non-rooted cuttings was less than on the corresponding rooted cuttings and there was more variation between branches and positions, viz. 1.5 to 2.5 per cutting in the former, and 1.6 to 2.4 leaves in the latter.

Discussion of Experiment II and IIa.

The experiments gave no significant evidence of differences between treatments. At the same time the precision of the experiments was reduced by the elimination of one clone from the experimental results in Experiment II and one block in Experiment IIa.

An examination of the results, however, shows a consistent trend with respect to the superiority of basal cuttings over apical cuttings as expressed by the number of cutting rooted, the average number of roots per cutting and the average weight of roots per cutting. The RE values for basal cutting were 16 and 17 higher than for apical cuttings. The average number of roots per cutting was to 47 percent greater in the case of basal than apical cuttings, whilst the average weight of roots per basal cutting was 47 percent greater than per apical cutting.

The trend in rooting behaviour of cuttings from the different branches, on the other hand, shows a much higher degree of uniformity. The variation in number of cuttings rooted between the types of branches was 6 to 8 percent; in average number of roots per cutting 8 to 16 percent; and in the average weight of roots per cutting 10 percent. These relatively small variations emphasize and lend weight to the importance of the difference noted for the positional effect on rooting behaviour.

There was some indication that clone 677 shows more vigorous rooting than clone 221, having 19 percent more roots per cutting whilst the average weight of roots per cutting was 29 percent greater for 677 than 221. At the same time there was a variation of only three in the RE values.

It is generally accepted that all cuttings have in varying degrees a natural potential for rooting. This rooting potential is expressed both in the vigor of rooting and the length of time necessary for rooting. It would appear that rooting is determined by the whole complex entering into the growth and development of the plant from which the cutting is taken. Thus a factor which affects the growth of the parent plant may also affect the rooting behaviour of cuttings taken from that plant (8). In addition the rooting behaviour of the cutting gives expression of its tolerance of the environment as well as to its natural rooting ability (9).

It has been shown that cuttings made from the first three nodes (apical) of the orthotropic stem of Coffea arabica had a higher rooting potential than the second three nodes (basal). The explanation offered is the difference in relative maturity of the tissues below the fourth and third node, the latter being relatively juvenile (8). The factor of envirnnmental tolerance was apparently not considered. The habit of growth of cacao in "flushes", makes it unlikely that there is any difference in juvenility among the nodes within a "flush" as is the case with the apical and basal cuttings used in these experiments.

A measure of environmental tolerance is provided by the number of non-rooted cuttings remaining alive. Results in both experiments indicate that there is no evidence of any note-worthy differences in the number of cuttings remaining alive for branches or position. In the former the differences were of the order of three to seven percent and the latter three to nine percent. The largest difference noted was 13 percent between the two clones in Experiment II.

Considering now the proportion of live cuttings to rooted cuttings there is experimental evidence which indicates a noteworthy difference between basal and apical cuttings An examination of the results show that 20 percent and 14 percent more basal cuttings rooted than apical, as contrasted with a maximum of 10 percent variation among branches and between clones. This would seem to indicate that there is some factor or factors associated with basal cuttings, other than the survival or juvenility factor which affects the rooting behaviour of cacao cuttings.

Whatever, the nature of the factors which bring about active cell division and differentiation of root primordia in the cambial area, they are more favorable in the tissue of the basal cutting, than in the apical cutting. The difference in rooting behaviour of these two types of cutting could be explained on the basis of the localisation of the normal rooting potential in favour of the basal cutting.

An additional feature of interest in the results, relates to the leaf survival in the course of the experiments. The number of leaves per cutting set was four, while the number of leaves per rooted cutting at the end of the rooting period in Experiment II was between 2.5 and 2.7 for both clone and position; and 2.2 to 3.3 for branches. A higher proportion of leaves was retained by cuttings in Experiment IIa, between 3.0 and 3.2 irrespective of the type of cutting. Thus in the process of rooting leaf losses of 18 to 45 percent, and 20 to 25 percent were sustained in the two experiments.

In the case of non-rooted live cuttings the number of leaves remaining at the end of the rooting period in Experiment II was between 1.4 and 2.2 for all of cuttings; and in Experiment IIa, 1.5 to 2.5 for both position and clone. Thus the leaf loss of the non-rooted cuttings was 55 to 65 percent, and 38 to 60 percent in the two experiments. The rooted cuttings therefor retained 20 to 47 percent and 18 to 35 percent more leaves in the two experiment than the non-rooted cutting. To what extent the increased leaf surface of the rooted cutting was responsible for rooting, it is not possible to evaluate on the data available. These findings tend to confirm the conclusion arrived at in Experiments I and Ia i.e. that further research on the leaf requirements for optimum rooting is necessary.

In commercial cacao cuttage stem cuttings are prepared with four to eight leaves, and it is the practice to trim the material from the basal rather than the apical end. In the case of single leaf cuttings the apical node and tip leaf is not used as it is reported that the terminal bud fails to sprout. Indications that higher rooting potential is determined, at least in part by the nodal position suggests that the rooting gradient of the growth flush should be evaluated. This could indicate the nodal positions which have the highest rooting potential. This would in fact be complementary to the research on the problem of non-rooted live cutting and the leaf requirement in cacao cuttage indicated by the results of Experiment I and Ia.

It could also have practical implications in the pot-rooting method by providing a means of selecting cuttings with a high rooting potential and thereby reduce the number of cuttings which fail to root, and the need to identify them.

Conclusions of Experiments II and IIa.

1. The propagating equipment described did not provide satisfactory control of the air-moisture relationship of the rooting medium in experiment II. Satisfactory control of this factor was obtained in Experiment IIa. by subtituting frames fitted with glass for those with cloth covers.
2. Under the conditions of the experiments the results obtained indicate a marked difference in rooting behaviour of apical and basal cuttings, the latter showing a higher RE and a greater number and weight of roots per cutting.
3. There was no apparent difference in the rooting behaviour of cuttings obtained from different types of branches, i.e. primary, upper secondary and lower secondary.
4. Clone 677 appeared to show more vigour in rooting than clone 221, as measured by the average number and weight of roots per cutting.
5. Results obtained in the experiments described, clearly indicate the need for further research to determine the variation in the

natural rooting potential of the nodal positions along the "growth flushes" used as cutting material. The establishment of such a rooting gradient, together with an evaluation of the stem leaf ratio requirements, as previously suggested, could have far reaching practical application in the selection and preparation of cuttings with a high rooting potential.

SUMMARY

Experiments to evaluate the pot-rooting method of cacao cuttage and to investigate the effect on rooting behaviour of the source and position of the cutting on the parent tree havebeen described.

The propagating equipment used did not provide satisfactory control of the air moisture relationship in the rooting medium in the first three experiments but control of this factor was obtained in Experiment IIa. by using glass covers over the propagating bins.

The experiments gave no evidence of significant differences between treatments, but evaluation of the results nevertheless provided information of highly suggestive value.

The pot rooting method did not prove to be more efficient in converting a cutting into a plant than the standard method. As it appears likely, however, that the optimal air moisture relationship of the rooting medium is within narrower limits for the former method, the results might be considered inconclusive.

It has been demonstrated that more economical use of propagating space can be obtained by using pots of smaller dimensions than the normal size used in these experiments.

There was no apparent advantage in using soil surrounding the rooting medium, but this result could also be considered inconclusive because of its dependance upon the air moisture relationship factor.

The problem of selecting the rooted cutting before placing in the storage area, in the pot rooting method, was overcome in these experiments by a combination of root penetration of the pot, and slitting of

the pots which had no roots visible.

Rooting behaviour of the cutting appears to be influenced by its position within the branch, basal cuttings showing a higher rooting potential, as measured by the number of cuttings rooted and the number and weight of roots per cutting than the apical. On the other hand the source, as represented by the different types of branches did not appear to affect rooting behaviour.

There was no difference in the RE of the clones but UFCo clone 677 appeared to show more vigorous rooting than UFCo clone 221 as expressed by the number and weight of roots per cutting.

The results have also given interesting and valuable information on the survival of non-rooted live cuttings and the loss of leaves during the rooting and hardening process. Cuttings remaining alive without producing roots at the end of the experimental periods were in the order of 21 to 39 and 17 to 40 per cent for six leaf and four leaf cuttings respectively. The loss of leaves varied between 18 to 60 per cent for rooted and 38 to 65 for non rooted cutting. No previous evaluation of these factors in cacao cuttage has been recorded in the literature examined by the author.

The results of these experiments have served to define more clearly further research needed on certain phases of the internal factors affecting the rooting of cacao cutting. These relate to the evaluation of the rooting gradient of the growth flush from which cuttings are prepared, and the optimum leaf-stem ratio requirements. Such information would determine the size of the cutting and its nodal composition for obtaining a high rooting potential.

Such information could have far reaching practical application in commercial cacao cuttage by making the most efficient use of the cutting material, with a consequent increase in propagation efficiency.

SUMARIO

Ensayos para evaluar el método de enraizamiento de estacas de cacao en macetas, y para investigar el efecto de la fuente y posición de las estacas del árbol madre en el comportamiento del enraizamiento han sido descritos.

El equipo de propagación usado no proporcionó control satisfactorio de la relación de la humedad del aire en el medio de enraizamiento en los tres primeros experimentos, pero control de este factor fué obtenido en el Experimento IIa usando cubiertas de vidrio sobre la caja propagadora.

Los experimentos no suministraron evidencia de diferencias significativas entre los tratamientos, pero la evaluación de los resultados sin embargo suministraron información de valores altamente recomendables.

El método de enraizamiento en macetas no probó ser más eficiente que el método estandard en convertir una estaca en una planta. Como parece probable, sin embargo, que la relación óptima del aire húmedo del medio de enraizamiento está dentro de límites estrechos para el primer método, los resultados pueden ser considerados inconclusos.

Ha sido demostrado que el uso más económico del espacio propagador puede ser obtenido usando macetas de dimensiones más pequenas que las de tamano normal usadas en este experimento.

No hubo ninguna ventaja aparente en usar tierra alrededor del medio de enraizamiento, pero este resultado puede también considerarse inconcluso debido a que depende de la relación del factor de humedad del aire.

El problema de seleccionar las estacas enraizadas antes de colocarlos en el área de almacenamiento, en el método de enraizamiento en macetas

fue superado en estos experimentos por la combinación de la penetración de raíces de la maceta, y las hendiduras de las macetas que no tenían raíces visibles.

El comportamiento del enraizamiento de las estacas parece ser influenciado por su posición dentro de la rama mostrando las estacas basales más que estacas apicales en enraizamineto potencial más alto, medido por el número de estacas enraizadas y el número y peso de raíces por estaca. En cambio la fuente, representado por los tipos diferentes de ramas no parecieron afectar el comportamiento de enraizamiento.

No hubo diferencia en el medio de enraizamiento de los clones pero el clone UFCo 677 aparentó mostrar un enraizamiento más vigoroso que el clone UFCo 221 expresado por el número y peso de raíces por estaca.

Los resultados han suministrado también información de interés y valor en la supervivencia de las estacas vivas no-enraizadas y la pérdida de hojas durante el enraizamiento y el proceso de endurecimiento. Las estacas que permanecieron vivas sin producir raíces al final de los períodos experimentales variaban de 21 a 39 y de 17 a 40 porciento para estacas de seis y cuatro hojas respectivamente. La caída de hojas varió para estacas enraizadas entre 18 a 60 porciento y de 38 a 65 porciento para estacas no-enraizadas. Ninguna evaluación previa de estos factores en estacas de cacao ha sido registrada en la literatura.

Los resultados de estos experimentos na servido para definir claramente la necesidad de fomentar la investigación de ciertas fases de los factores internos que afectan el enraizamiento de estacas de cacao. Estos se refieren a la evaluación del gradiente de enraizamiento de la abundancia de crecimiento de los cuales las estacas son preparadas y las necesidades óptimas de proporción hojas-tallos. Tal información determinaría el tamaño de las estacas y su composición nodal para obtener un alto potencial de enraizamiento.

Información de este tipo podría tener aplicaciones de largo alcance en estacas de cacao comercial por medio de el uso más efectivo del material de estacas con uh aumento consecuente en la eficiencia de propagación

LITERATURE CITED

1. ALVIM, PAULO DE T. Nuevos propagadores para el enraizamiento de estacas de cacao. Centro Interamericano de Cacao (Turrialba, C. R.) Cacao 2(47-48):1-2. Nov.-Dec. 1953.

2. _______ & DUARTE, OVIDIO. Mejores preparaciones hormonales para el enraizamiento de las estacas de cacao. En Comité Técnico Interamericano del Cacao. 5a Reunión. Trabajos presentados. Turrialba, C. R., Instituto Interamericano de Ciencias Agrícolas, 1954. vol. 1, Sección Propagación, doc. 6. 13 p.

3. BURCHARDT, AKE & JORGENSEN, HENNING. A preliminary note on cacao work at Hacienda Clementina, Ecuador. Inter-American Cacao Center (Turrialba, C. R.) Cacao 2(7):1-3. July 1950.

4. DESROSIERS, RUSSELL & VON BUCHWALD, ANGEL. Fungicidal treatments for control of cacao cutting disease in Ecuador. FAO Plant Protection Bulletin 4(2):17-21. Nov. 1955.

5. DE VERTEUIL, L. L. Cacao cuttage in the Western Hemisphere. Turrialba, C. R., Inter-American Institute of Agricultural Sciences. In press. (Miscellaneous publication no. 8)

6. ERICKSON, ARNOLD L. Procedures used for rooting of cacao cuttings at the Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica. Comunicaciones de Turrialba no. 54. June 1955. 4 p.

7. EVANS, H. Recent investigations on the propagation of cacao. In Imperial College of Tropical Agriculture. A report on cacao research, 1945-1951. St. Augustine, Trinidad, 1953. pp. 29-37.

8. FIESTER, DONALD R. Some aspects of the asexual propagation of coffee by cuttings. Unpublished thesis. Turrialba, Costa Rica, Inter-American Institute of Agricultural Sciences, 1952. 92 p. (typewritten)

9. GARNER, R. J. & HATCHER, E. S. The influence of source and growth substance on the behaviour of apple and plum cuttings. Journal of Horticultural Science 30(2):116-128. April 1955.

10. PLANT improvement. In Comité Técnico Interamericano del Cacao. 5a Reunión. Recomendaciones y trabajos adicionales presentados. Turrialba, C. R., Instituto Interamericano de Ciencias Agrícolas, 1954. vol 2. Sección Recomendaciones, Sub-com/1 doc. 30. 3 p.

11. PYKE, E. E. The vegetative propagation of cacao. I-V. Imperial College of Tropical Agriculture (Trinidad) Annual report on cacao research 1:4-9 (1931), 2:3-9 (1932, 3:4-11 (1933). 1932-1934.

I. A survey of possibilities. II. Softwood cuttings. III. Observations on varietal differences in the rooting behaviour of cacao cuttings. IV. Propagation by softwood cuttings under estate conditions. V. Notes on the dimorphic branching habit of cacao.

12. SNEDECOR, GEORGE W. Statistical methods applied to experiments in agriculture and biology. 4th ed. Ames, Iowa State College Press, 1946. 485 p.

13. STAHEL, GEROLD. De bladstekken-methode voor het vermenigvuldigen van cacao. Suriname Department Landbouwproefstation Bulletin no. 61. Juni 1948. 15 p.

APPENDIX 1

Analysis of Variance

Experiment 1. Evaluation of the pot-rooting technique.

Source of Variation	D.F.	Mean Square Values for: Percent cutting alive	Percent cutting rooted	Average number of roots/cutting	Average weight of roots per cutting	Percent plants produced
Total	15					
SS Rows	3	41.63	60.84	3.53	0.37	101.83
SS Columns	3	89.85	23.74	2.97	0.33	89.66
SS Treatments	3	41.63	39.24	3.40	0.28	164.83
SS Error	6	86.55	50.18	2.44	0.13	76.93

APPENDIX 2

Analysis of Variance

Experiment 1a. Evaluation of the pot-rooting technique.

		Mean Square Values for:				
Source of Variation	D.F.	Percent cutting alive	Percent cutting rooted	Average number of roots/cutting	Average weight of roots per cutting	Percent plants produced
Total	15					
SS Rows	3	225.79	59.19	3.73	2.68	91.61
SS Columnus	3	40.69	50.26	11.15	0.72	76.18
SS Treatments	3	460.27	314.27	1.27	0.33	76.18
SS Error	6	109.51	69.55	2.78	0.21	169.31

APPENDIX 3

Analysis of Variance

Experiment II. The effect on rooting behaviour of the source and position of the cutting on the tree.

		Mean Square Variance for:			
Source of Variation	D.F.	Percent cutting alive	Percent cutting rooted	Average number of roots per cutting	Average weight of roots per cutting
Total	23				
Replications	1	-	-	1.55	0.10
Clone	1	2.67	0.17	9.25	0.77
Error (a)	1.	0.14	0.67	1.17	0.35
Position	1	0.17	4.17	51.92	2.74
Position x clone	1	0.66	0.17	4.95	0.39
Error (b)	2	1.25	1.42	4.09	0.43
Branch	2	0.04	0.54	0.58	0.08
Branch x position	2	0.29	0.29	2.34	0.47
Branch x position x clone	2	0.29	0.79	0.02	0.02
Error (c)	8	1.54	0.94	2.37	0.10

APPENDIX 4

Analysis of Variance

Experiment IIa. The effect on rooting behaviour of the source and position of the cutting on the tree.

		Means Square Values for:		
Source of Variation	D.F.	Cuttings alive	Cuttings rooted	Av. N° of roots per cutting
Total	17			
SS Blocks	2	1.0	4.54	4.79
SS Treatments	5	1.0	0.73	2.61
SS Error	10	0.9	0.42	3.13