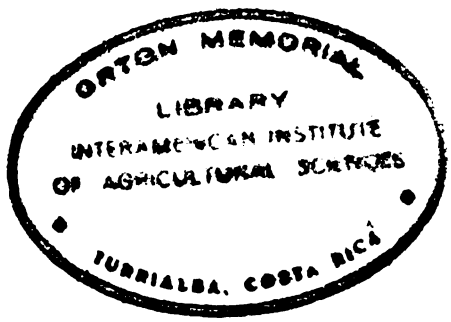
PRELIMINARY STUDIES IN REPLANTING CACAO IN COSTA RICA

By

Ellis Martin



Inter-American Institute of Agricultural Sciences
Turrialba, Costa Rica
December, 1957

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A Thesis

Submitted to the Graduate Study Council in
partial fulfillment of the requirements for
the degree of

Magister Agriculturae

at the

Inter-American Institute of Agricultural Sciences

APPROVED: _____ Chairman

_____ Committee

_____ Committee

December, 1957

To my beloved parents and wife

ACKNOWLEDGMENT

The writer wishes to acknowledge his indebtedness to his Advisor, Mr. 3. Havord, under whose direction this study was completed, for his invaluable help and for his guidance.

To Dr. J. León, Dr. L. R. Holdridge and Prof. F. Hardy for reading the manuscript and offering helpful suggestions.

To the International Cooperation Administration for providing the assistantship to carry on the investigation.

To the Inter-American Cacao Center of the Inter-American Institute of Agricultural Sciences for facilitating the opportunity to conduct the investigation at the experimental and commercial cacao farm "La Lola", Costa Rica.

To Mr. A. Paredes, farm overseer of the "La Lola" farm for his help and assistance, especially in the absence of the writer in supervising the necessary operations of this project.

To Miss Angelina Martínez, Librarian of the Inter-American Institute of Agricultural Sciences for valuable assistance and help in reviewing the literature.

To Mr. H. Granados for his services with the multilith in printing this thesis and to Mr. J. Pérez who assisted him in the drawing of the maps and diagrams.

V I T A

The writer was born on January 15th, 1924 in Surabaya, Java, Indonesia (the former Netherlands East Indies). After finishing high school in Java, he entered the State College for Tropical Agriculture, Deventer, The Netherlands, in September 1947 where he was awarded the Degree of Bachelor of Science in Agriculture, with a major in Tropical Agronomy, in June 1950.

He enrolled in the Graduate School of the Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica, in June 1955, where he was appointed to a graduate assistantship by the International Cooperation Administration (ICA) to conduct investigations in cacao production and to assist in the training of trainees in the field of cacao technology.

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I INTRODUCTION AND SCOPE OF STUDY

There has been a small cacao industry in Costa Rica for many decades, but larger commercial plantings were started in 1914 by the United Fruit Company. Banana fields which had been devastated by the Panama disease (Fusarium cubense) were replanted with cacao of seedling origin (8). The cacao in Costa Rica is planted in the Caribbean lowlands and the fertile alluvial soils seem to be suitable for the satisfactory growth of this crop (16). The production in this country is not high and fluctuates between 6000 and 9000 tons annually. In 1932, it was reported that the average yield was 500 to 700 pounds of dry cacao per acre (8). The current yields, however, are much lower and may be put at 150 pounds per acre. In cacao plantings which are regularly sprayed against the black pod disease, a fungus disease, (Phytophthora palmivora) average yields are much higher and may vary between 300 and 600 pounds per acre.

Owing to uncertainty of price movements, proper and regular maintenance of the cacao stands in Costa Rica has been neglected, resulting in an uncontrolled growth of the trees. Despite improvement measures in semi-abandoned farms, such as disease control, sanitation and replanting low bearing trees with improved plant material, the cacao industry in this country has not proved to be economic in times with prevailing low prices on the world market.

In view of the pressing need for better cacao husbandry, it may possibly be less profitable in the future to work with such partly revived cacao fields. Therefore, facing the necessity of complete replantings in the future, it was felt desirable to investigate the possibilities of replanting cacao in Costa Rica. The aims of such a replanting program should be based on:

1. Reducing the size and volume of the new trees in order to make maintenance and harvesting operations simple and economical;
2. Increasing the individual tree yields, but reducing the variability in yields from tree to tree.

Consequently, a replanting project was started and a pilot plot was established at the experimental and commercial cacao farm "La Lola". The objectives of this project were threefold:

(a) To calculate the cost of establishing new plantings;

(b) To stress the need for improved cultural practices in the new plantings;

(c) To analyze the growth performance of three types of asexually propagated cacao.

The relative economic merits of the different planting material and the financial return of the whole operation will of course depend on the yields of the new cacao. This paper covers only the first two years of the establishment period.

The experiment aimed to replant immediately, after a complete felling and clearing, about 3 acres of an old cacao stand. Using mechanical appliances, the old cacao trees were lifted out with their principal roots attached and transported outside the experimental area to be cut and stacked. In this way the efficiency and the cost of mechanical removal could be analyzed and a rough comparison could be made with the traditional system of felling trees at ground level and piling up the debris in rows. The cleared area was replanted to rooted fan cuttings and seedling rootstocks; these stocks were patch budded at stake after a year of growth with chupon and fan material. The seedling stocks were grown from seed of the ordinary green and thick shelled Amelonado type cacao. For both the cuttings and the buddings, two superior UFCo cacao clones (United Fruit selections) were used, i. e. UFCo 667 and UFCo 650.

The reasons for using vegetatively grown material are the following: very little is known in Costa Rica about survival, relative

cost, field performance and desirable shape of future cacao trees. Since a markedly disuniformity in pod type and tree productivity of some UFCo selections was observed in small seedling plantings in Costa Rica, the method of propagation by seed was not used in this experiment. In general, the asexual method in cacao propagation gives consistent and reliable results and, to a certain extent, reduces the effect of disuniformity of hybrid material. In order to avoid a possible and undesired effect of such hybrid seed on scion growth, the rootstocks were all grown from seed of the earlier mentioned Amelonado type of cacao. Seed of this material is rather small, flattish and dark purple coloured when cut. In contrast, the UFCo selections have larger, plumpish and violet colored seed in cross section.

The young cacao was spaced 4 x 4 mts. and 3 x 5 mts. By using the latter system, the number of plants in the same unit can be increased by 7 percent and the wider interrows might offer possibilities for mechanical operations. The effect of the spacing on productivity may be observed in the future when the trees mature.

Because of a possible soil deterioration, the physical conditions and the nutrional level of the soil were improved, using the so-called "Hulpgewassen". The latter is a Dutch term for "aid plants" and usually refers to legumes. A banana variety which is not affected by the Sigatoka disease, a leaf blight disease (Cercospora musae), was planted for two reasons: (a) to act as a temporary shade and (b) to obtain a revenue from the sale of the bananas. In addition, these bananas provide a good and cheap source of organic matter. Since young cacao generally thrives best under a proper shade, temporary shading could not be omitted. In sites where the bananas failed to grow, a broad leafy tree legume, Erythrina poeppigiana, was planted from stakes. Since this species has a rather deep root system, the effect on internal drainage and soil structure could be observed. Besides, the root nodules and the leaf fall may provide a good source of ready-available nitrogen for the young cacao.

Once the cacao was planted, emphasis was laid on vigorous growth and future shape of the plants. This involved soil tillage, the regulation of the temporary shade and the use of mulch, which was obtained from the loppings of the temporary shade. During the period of establishment, it was possible (a) to observe the effect of shaping young cacao, (b) to test the technique of pruning cacao and (c) to analyze the economics of pruning on three types of vegetatively-propagated cacao. Especially the economics will be of importance in the case of rooted fan cuttings, owing to the variability in growth habit.

In order to evaluate the investment made, complete cost records were kept for further analysis. It is understood that cost data should be kept until the young cacao becomes well established and commences to bear fruit.

II REVIEW OF LITERATURE

Background of Cacao Rehabilitation

As a result of an investigation in old cacao fields in Trinidad, Hardy (10) using Shephard's data, reported that the greater part of the production was obtained from a very small number of trees. The findings in a plot of 100 trees are summarized below:

	Good Soils	Poor Soils
Bearing trees	64	50
Productivity per acre	290 pounds	90 pounds
Production per tree	1.3 "	0.4 "

Shephard (22) gave two reasons for the accumulation of poor and inferior trees. These were: the "supplying" of blanks all over the estate, and the failure to remove damaged trees. Since the supplies were scattered over the fields, proper maintenance could not be done and special vigilance was required to prevent cutlassers from injuring these young plants. The same authority seems to hold the opinion that rehabilitation could not be carried out profitably on poor soils. The reason appeared to be that the yields of the original trees on poor soils seem to diminish after 20 years, indicating a decline in soil fertility.

These findings and observations as indicated above, clearly explain the extensive method of cacao husbandry nowadays applied in Trinidad, and secondly, they seem to stress the need of cultivation of cacao in "good" soils only.

The current yields in the "La Lola" farm, Costa Rica, of 600 pounds, and in one section of 1200 pounds of dry cacao per acre, clearly indicate that, despite ordinary seedling material, higher yields than those obtained in Trinidad can be attained. The limiting factors in growing cacao in the Atlantic region of Costa Rica are: (a) the excessive rainfall in certain months of the year, and (b) the black pod disease. In

view of the fertile status of these alluvial soils, it would probably be of less importance to conduct in this country a survey in old cacao plantings as it was done by Shephard in Trinidad.

Aims and Methods of Rehabilitation

The essential aims in attempting to rehabilitate old cacao lands should be the protection of the soil, the maintenance of the right atmospheric conditions near its surface and the conservation of crumb soil layer with its abundant cover of decomposing litter (9).

In Trinidad (22), it is recommended that the initial program of rehabilitation should be divided in two phases: firstly, to replace all inferior trees, and secondly, to replace the trees which give lower yields than can be expected from the replacements. This problem of replacing non-and poor bearing trees in old cacao plantings has led to a series of investigations which principally were undertaken in Trinidad. The views of various workers are further amply explained below.

Pound (18) seems to favor the method of partial rehabilitation. He recommends the replanting in groups of not less than six plants. In this way there is less competition of the surrounding old trees than when just isolated spots are replanted. Consequently, the maintenance of such groups should be more effective and economical. Cheesman (2) suggests the replanting of four percent of the area with clonal material annually. At the end of 5 years, twenty percent of the farm is out of production but afterwards the production will increase each year in proportion. At the end of 25 years the whole farm will be completely rehabilitated.

Hardy (11) advises in his report about the rehabilitation program in Haiti to replant completely section per section. He does not recommend completely replanting an area, but leaving the younger shade trees. The older shade trees may fall over sooner or later and may cause considerable damage to the young cacao.

Urquhart (26), in 1953, reported that, in one estate in Grenada, the cost of establishing a cacao field with clonal material was repaid at the end of five years. The system is based on raising food crops for two or more years. However, where cost of transportation of food crops is high, little or no profit may be derived from their sale. Since financial assistance is being offered at present to cacao farmers in Trinidad, whole blocks of old cacao can be replanted and the income from food crops will help to offset expenses in the early years (26).

All workers seem to support the idea of leaving cut up trees to decay. Miranda (17) suggested to line up the cut up trees in rows leaving strips open for the replanting of cacao. The debris of the cut up trees will quickly decay and consequently this will reduce weeding costs and control erosion. The decaying mass will also release plant nutrients which will become available for the young cacao. Also, the debris is a good source of organic matter.

Choice of Cacao Plant Material

In a replanting program the choice of plant material is of vital importance. The requirements are:

1. A potential high yielder
2. A low coefficient of variation of pods per tree and beans per pod.

Urquhart reported (26) that, with a few exceptions, uniform results cannot be expected from selected cacao seed at the present time. Vegetatively-propagated material seems to give consistent results. The disuniformity of seed of clonal stock was also reported by Pound (21) and Jolly (14). Urquhart (27), in 1953, communicated that the Gold Coast Amelonado cacao breeds true to type and gives a uniform product from seed. However, the yield is only 1 pound to 1½ pound per tree, against 6 to 6½ pound per tree for the Keravat cacao of Australian New Guinea.

Another point of interest is raised by Jolly (14), who reported that, under conditions in Trinidad, the survival after three years in the field was 55 percent for clonal seedlings against 76 percent for clonal cuttings. The reason for this difference, according to this worker, is that the cuttings are larger and do not depend on a single growing point.

The methods of vegetative propagation which are now generally applied involve buddings and cuttings. The pros and cons of these two materials are summed up by Pound (21). This worker reported that cuttings grow on their own roots against buddings on borrowed roots. These foreign roots may induce later a stock scion incompatibility. However, according to the same worker, foreign roots are to be preferred in some cases. They may give a greater vigor to a weak Criollo scion, thus causing a dwarfing effect and besides they may be resistant to certain root diseases. The same worker further indicates that seedling roots lack uniformity, but yield performance of budded scions is less variable (about 30 percent) than a seedling progeny.

Since Topper (25) has demonstrated that scions after being budded can also be rooted, the problem of borrowed roots (21) of the buddings has apparently lost its importance. Rooting may be induced by treating a cut in the scion with rooting hormone and further moulding with soil above the bud union.

When promising and uniform plant material is available, the planting of seedlings may be recommended. However, when this is not the case, the propagation should be carried out asexually. Since clonal fan cuttings grow fast, produce early and become mature sooner than seedlings, the propagation of rooted cuttings is being stressed. Despite its good features, the Compañía Bananera in Costa Rica discontinued the planting of rooted cuttings in the Atlantic region a few years ago. The reasons were a low survival in the field and a high cost of establishment. These poor results may be due to the facts that (a) pre-planting operations

were not properly done (temporary shade), and (b) the after-care of the tender plants after planting was not sufficiently supervised.

Cope (3) in 1952 reported that, in clonal trials in Trinidad, cuttings generally outyielded buddings in the group of good clones. With maturity, yield differences became less marked. In the poor group, buddings were frequently more efficient than cuttings. The same worker indicated that the different behaviour of clones as buddings and as cuttings may be due to the possession of a root system more "efficient" than that of the average seedling. Since in the poor group of clones, buddings outyielded cuttings, the choice of a selected rootstock having an "efficient" root system for budding purposes appears to be of primary importance.

Topper (24) is the first worker to reject the method of raising cuttings for the purpose of planting at large. It is more economical to make use of buddings, and he strongly recommends the method of budding at stake. Pound (19) in 1939 indicated that, in a replanted field in Trinidad, budded trees may yield nearly 1000 pounds of dry cacao per acre in the seventh year after planting the buddings. Such a yield is sufficiently high to satisfy the demands of farmers for higher yields.

The Technique and Cost of Asexual Propagation

The rooting process of cacao cuttings in concrete bins is well described by Erickson (4). Softwood cuttings are dipped at the base in a root inducing hormone and further propagated in a sawdust medium. The cuttings are usually rooted in 4-5 weeks and hardened in two weeks more. The rooted plants remain in the storage shed until they have completed their second flush. This whole process will take about 5 months and, in general, two cuttings will yield one rooted cutting.

The cost of producing rooted cuttings using the concrete bin is

too high to be economically justified. Hardy (11) reported that the overall price per rooted cutting delivered at the farm in Trinidad may amount to (BWI) $1.00; thus an expense of $200.00 per acre for plant material or about 20 percent of the total cost for re-establishment. De Verteuil (28), in 1955, reported that the cost per rooted cutting produced in Costa Rica is ₡2.00 (Costa Rica currency), excluding overhead expenses. The latter is equivalent to about US$0.30.

The production of rooted cuttings is limited by (a) a low efficiency and (b) a high cost owing to a high capital investment, and to expensive maintenance. Adopting the suggestion of Archibald (1), the production of rooted cuttings can possibly be done cheaply, having a high efficiency at the same time. In the experiments in West Africa, the cuttings are rooted in the open in a container made of boards with a movable polyethylene cover. The cuttings may be rooted in a core of sawdust, or any good medium inside a polyethylene tube. During the period of rooting, watering is reduced to a minimum. Owing to the polyethylene cover, a high relative humidity can be maintained throughout the rooting process. Once the roots are visible through the transparent wrapper, hardening can commence. Plant losses at this stage can be avoided, since transplanting is not practiced. In his experiments, Archibald claims to have obtained a high percentage of rooting and, since the overhead and maintenance expenses are little, the cost of producing rooted cuttings apparently is economical. Besides, propagation can be carried out right on the farm. However, rooted cuttings are generally planted after the second flush is hardened; such plants ought thus to be maintained in good condition for about three months longer. It is not likely that a high efficiency can be maintained until planting time, owing to the common lack of proper care on small farms. Since sturdy and thus older plants usually give a higher survival rate after planting in the definite site, the problem in producing low cost rooted cuttings apparently

remains unsolved.

The other method of asexual propagation of cacao is the budding method. In Java (13), a standard procedure has been prepared for budding on an estate scale. When the right technique is followed, successful bud growth of not less than 90 percent is obtained. In Trinidad, as reported by Pound (21), the percentage of success, after losses at various stages, amounted to less than 30 percent. Since rooted cuttings are being produced at about 50 percent efficiency, the latter method is preferred in Trinidad. The results which are obtained in two distinct areas (Java and Trinidad) apparently were never well explained. In Java, and also in Malaya (13), the buddings are made at stake on plants which are 1½-2 years in the field. The stock diameter may vary between 2½ and 3½ cm. In Trinidad, however, the method of making buddings in a nursery is preferred. It is obvious that a comparison of results in Java and Trinidad cannot be made. Nursery plants are usually less than nine months old. Budding of older stock plants is not economical since transplanting of budded planted is expensive.

Apart from using the right technique, less or no attention is being paid to the origin of the stock plant. Jones (15) in 1915, suggested making use of hardy and uniform material. He recommended the hardy Calabacillo cacao. Pound (18) in 1946, reported that,with the exception of Brazil, there is a general decline of cacao production in all areas. Since the Calabacillo variety prevails in the cacao plantings in Brazil, this variety seems to offer possibilities as a rootstock, especially of value against soil-borne parasites. The significance of the rootstock problem on scion growth when budding is practiced at stake was amply discussed by Tollenaar (23) in 1941. This worker found in Java a correlation between growth givor of the stocks and the growth vigor of the scions. The Forastero cacao appeared to show the most vigorous growth and, when budded at stake with white seeded hybrid cacao, a vigorous growth of the scion was usually observed. However, within the Forastero subspecies there

seem to exist wide differences in growth vigour. The selection of vigorous growing stock plants, but showing less variability in growth, appeared to be of importance when proper results of the patch budding method are required. As also indicated by Tollenaar, it would be very interesting to check the final budding results when such budded trees mature.

The standard procedure for budding at stake, and using the Forkert method or patch method in Java (13), is given below. Seedling stocks usually are two years old and they have a stem diameter of at least one inch. Budwood is obtained from gardens specially planted for the purpose of supplying budwood. One metre of budwood of about an inch in diameter may yield 15-20 buds. First, two horizontal cuts and one vertical cut are made in the stock plant, and the bud of about the same size is inserted behind the flap in the stock plant. The operation of budding is based on speed and care. A minimum of 150 buddings can be made per man day with an efficiency of 90 percent. Budding should not be done on rainy days nor when the stock plants are still wet.

In order to obtain good results in buddings, two points were stressed by Harris (12) in 1903. Between the wood and the bark, the existence of a cambium layer is apparent which is made up of several layers of thin-walled, rapidly-growing and dividing cells. On the removal of a piece of bark at budding time, it will be found that part of this delicate cambium has remained on the bark. To ensure success, speed is necessary in order not to expose this delicate cambium to dry air because it will wither and die. The second point is that care should be taken for the reception of the bud when inserted in the stock plant. It must be remembered that union takes place under the bud and not at the sides. The space for the bud must be large enough.

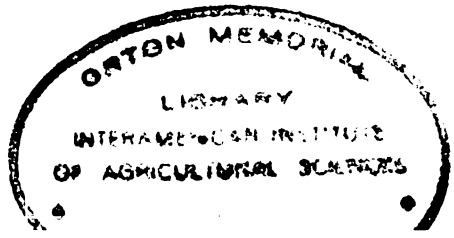
These two points which were mentioned above and were stressed in 1903, are often forgotten. The budding of younger stock material

and the use of thinner budwood usually give difficulties, since the wood does not separate quickly from the bark. Harris (12) stressed that the piece of bark containing the bud ought to be removed from the wood without bruising. It must be borne in mind that any bending will bruise or crush the cells of a plant.

Pound (21) gives some interesting information about the method of patch budding. The best buds are those when the protecting leaf has recently abscissed. He reports that before the leaf has abscissed the cortex is too soft and breakdown seems to occur in the tissue of the patch before union can take place with the stock. In order to break bud dormancy, the stock plant should be topped a month after budding. The leafy portion of the stock plant can be removed when the shoot is several inches long. The last operation of budding is a slanting cut close to the insertion of the bud.

Stahel, as cited by van Hall (8), recommended the bending of the stock plants after they were budded. The current procedure in Java (13) is to slit up the stock plants and to bend them over. In such a way the shoot can grow out without any interference of the stock plant. In Java (13) there is a preference for sucker type buddings, resembling the true seedling type tree. The shaping and after care are simple and cheap to perform. Pound (19) suggested that, when fan material is used, two buds might be inserted in the same stock. In this way he thinks a better balanced tree would be obtained.

The method of budding at stake, which is done in Java, Malaya, and in Surinam, is simple and easy to perform. Besides, this system is very cheap and gives consistent results. Since best results are being obtained at the time of flushing (19), the time of budding is restricted. Assuming two growth flushes a year, this will give about an optimum period of 3 months for budding. Assuming about 50 days of good dry weather, and an optimum of 150 buddings per man day, per man, 7500 buddings, occupying 15 hectares, can be carried out per year. It is just a matter of economics whether to apply



the nursery method (rooted fan cuttings) or the field method (budding at stake). It must be borne in mind that re-budding can be done, thus increasing the efficiency of budding at stake. As explained before, the efficiency of rooted cuttings is limited. With the method of budding at stake, a capital outlay for a propagation unit is not necessary as in the case of cuttings. However, in order to obtain best results in budding, it is essential to have the stock plants in good condition, and optimum care should be given immediately after planting the stocks in their definite site. Usually this is neglected and consequently budding results are not satisfactory. As explained earlier by Tollenaar (23), vigorous but non-hybrid rootstocks should be used when available. This should reduce maintenance costs until budding time and a high survival rate might be achieved.

Cultural Practices in Young Cacao Plantings

In most areas where cacao is grown, the cultivation of food crops in young cacao planting is practised. In areas under estate management, the stress is on proper growth of the young cacao. It is obvious that the cacao stands under estate management are more uniform and usually produce at an early stage. Urquhart (26) communicated in 1955 that, in replanting old cacao fields in Grenada, the practice is to grow bananas as a food crop and as shade, and to fork in 25 tons of pen manure per acre. Green (7) reported in 1938, that the banana is a heavy feeder and is of the opinion that the use of legume trees or shrubs should be rather stressed.

Since the methods for establishing cacao seem to vary from area to area, it is difficult to lay down definite rules for proper cultural practices. However, when old cacao fields are replanted, the process of building up a fresh crumb layer and the raising of the organic status of the topsoil must not be overlooked (9). Once the cacao is planted, weeding is considered to be one of the essential operations. Usually tillage and soil management are omitted being

regarded as superfluous (8), Urquhart (26) reported that light hoeing around young cacao seems to encourage the spread of the feeding roots. The same worker stressed the necessity for weeding by hand around the cacao plants, in advance of general cutlassing. The latter is necessary to avoid damage to the young plants.

In order to improve soil conditions, Pound (19), in 1939, recommended planters to incorporate animal or plant debris. The tap-root of a cacao seedling descends into the subsoil; laterals, however, rarely penetrate below 18 inches. Since there laterals are mainly confined to the top six inches, it seems thus essential to incorporate humus in the top six-inch layer.

Besides the necessity for temporary shade, young cacao needs protection against cold or drying winds (26). This problem was perfectly solved in Java. Legumes are planted from seed in the form of hedges alongside the cacao lines. These hedges should be established 6-12 months in advance. The most popular legume is Leucaena glauca which serves as a multipurpose plant. The system in Java is to prune such hedges periodically, leaving the loppings on the ground to decompose. Another suitable legume shrub is Tephrosia candida which also can stand frequent prunings (13).

In clonal plantings, working with rooted cuttings and buddings, the regulation of shade is essential. Evans (6) reported in 1952 that the best growth of rooted cuttings was obtained under 50 percent light. At 75 to 100 percent light, a symmetrical bushy type tree was obtained, while dorsiventral growth was observed at 15 to 25 percent light. Controlling light conditions seems to be very important, since the desired shape of the new cacao tree can be induced in the early stages of growth. The light factor is also very important when seedlings are grown in the field for rootstocks and which are to be budded at stake.

Little is known about the proper after care once the clonal cacao

is planted in the definite site. In order to induce a bushy growth, Topper (24) recommends staking the rooted fan cutting at planting time. Urquhart (26) reported that the aim in shaping is to produce a well-balanced frame work on which the fruit may be borne. The same worker further indicated the various methods and systems that have received little or no attention from the scientist; the only guidance available is the experience of the successful farmer.

III MATERIALS AND METHODS

The studies reported in this paper were carried out at the experimental and commercial cacao farm "La Lola", which is located on the Atlantic side of Costa Rica, from 24 to 58 metres above sea-level. The farm is situated along the railway linking San José and Limón, and the distance to the nearest seaport, Limón, is about 28 miles. The railway is the only means of communication.

Experimental Area

The experiment was laid out in Section 11 comprising an area of 1.66 hectares. The cacao trees in this area were assumed to be 40 years of age and the variety grown was the green thick-shelled Amelonado type cacao. The soil in this area is developed over alluvium derived from volcanic rocks and may be classified as a sandy loam with a pH of around 5.5. The area has a slight slope to the north with a depression near the center in the northwestern part. Along this depression, the soil is rather stony at and near the surface. A winding road crosses the experimental area in an east west direction and gives access to Section 12. This passage was made to provide access to Section 12 for the regular monthly spray. In planning this experiment, this access to Section 12 had to be maintained.

There are no drains within the experimental area, and, during heavy rains, a free surface run off may be observed. The excess of water is further absorbed by a deeper depression which crosses Section 12 in the northern part. The land of this area is not altogether flat, showing scattered low spots. The experimental area was sparsely shaded with about 50 percent of the cacao trees fully exposed. Shade trees of various sizes and species were encountered scattered over the area in an irregular pattern.

The production per hectare per year averaged 1500 kilos of wet cacao over the period 1952-1955. Until clear felling, the section was under regular fungicidal spray at a 45-day cycle. The cacao was spaced 12 x 12 feet, but, in the course of time, regrowth from fallen trees had altered the regular pattern of spacing. It was estimated that 25 to 30 percent of the original trees had disappeared. Little replanting was done, but the number of new suckers, which in most cases were productive, was numerous. The current farm overseer has stated that, in 1950, a plan was made to renovate this area by means of budding basal chupons. At clearing time, a small number of budded suckers were encountered. It seems that the budding experiment was discontinued soon after it was started.

Climatic Conditions

Rainfall data were abstracted from the records of the farm. Precipitation ranges from 105 to 173 inches per annum with a 8 year's average of 140 inches. The months of February, March, April, August and September are driest. Twenty-five percent of the annual rainfall falls in these months. The remaining months are wetter with increasing amounts of precipitation during the last quarter of the year (Tables 16 and 17). The relative humidity is 100 percent at night with a low of 70 percent at noontime. In the months with more sunhours, maximum temperature fluctuates between 30ºC and 32ºC at noontime. The minimum temperature in the corresponding months may fluctuate between 19ºC and 21ºC. Annual means for sunhours per day, temperature and relative humidity are 4 hours, 24ºC and 80 percent respectively. Additional weather data are presented in Tables 18, 19, 20.

Experimental Procedure

It was felt convenient to present the procedure in the following order:

A Experimental layout

B Schedule of operations

C Description of major operations

A. Experimental Layout

The experimental area is 115 metres long and 100 metres wide, comprising 1.15 hectares. The area was split up first into six blocks of equal size by constructing a middle road 2 metres wide and two other roads which run in opposite direction, having a width of 3.50 metres and 1.00 metre, respectively. Each block was 36 mts. long and 50 mts. wide, and consisted of 8 rows. These rows were lined up in the east-west direction. A block was further split up into two sub-blocks of 4 rows each. In each block the plants in the two sub-blocks were spaced 4 x 4 metres and 3 x 5 metres. The treatments were as follows: rooted fan cuttings, fan buddings and chupon buddings. An admixture of two cacao clones were used: UFCo 650 and UFCo 667.

A sub-block was finally split up into three plots of equal size and the three treatments were randomized within the sub-blocks. Each plot consisted of 16 plants, all propagated in the same way. In this area of 1.15 hectares, there were thus 12 replicates for the treatments and 6 of each spacing, comprising 576 experimental plants. * A plan of this experiment is shown in Fig. 1.

B. Schedule of Operations

The experiment was initiated on August 18, 1955, thus covering a period of almost 24 months.

The following sequence of the more important operations are set forth in Table 6.

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* Since the 3 x 5 metre sub-blocks were smaller in size than the 4 x 4 metre sub-blocks, six odd plots bordering the middle road were obtained. Such plots were planted to 16 rooted cuttings of an admixture of the same clones and the cacao plants were spaced 2½ x 5 metres.

C. Description of Major Operations

1. The clearing of old cacao and shade

Cacao trees were pulled out mechanically, using a 20 feet steel cable and a 10 feet long chain. The chain was put almost at ground level and attached to one cacao tree at a time and, with the tractor moving forward slowly, the cacao trees were lifted out with their principal roots attached. For this purpose, a John Deere--40 18 HP crawler tractor was used. Depending on their size, the cacao trees were transported to the far south-western end of the cleared area. The trees were cut up by hand and stacked along the tracks. It was estimated that about 10 trees could be pulled out per hour and some 20 trees could be cut up and stacked per man-day of 8 hours. One tractor operator and an assistant were used to transport the cacao trees to the stacking place; for cutting and stacking the old cacao trees one labourer was used.

Some thirty scattered shade trees were cut out by hand at ground level, leaving most of the roots in the soil. These trees were cut up in day labour, using three labourers. In the final clearing, the tractor was used to remove all remnants of wood and large stones from the experimental area.

2. Discing and Levelling

After the completion of clearing, discing operations were initiated. A one-way harrowing disc was mounted to the tractor and in both directions the area was disced. Some obvious-looking low spots were levelled off by hand.

3. Lining Up

For this purpose, 1.00 metre and 2.00 metre sticks were acquired; the large sticks were used to mark the border sites and roads, while the shorter ones were used to stake the future sites of the young cacao. The first and last plant of the plant rows were spaced in a single line but leaving a margin of two to

three metres of the main road and communication line.

4. Reshading

(a) Temporary shade

Some 600 rhizomes of Guineo negro (Musa sapientum L.) which were obtained from Turrialba, were planted out midway between the cacao plants in the cacao rows. Holing and planting of the rhizomes were done simultaneously. Seed of Crotalaria anagyroides was sown out 3 feet apart on both sides of the cacao rows in one inch deep furrows. It was observed that 200 gram of seed was required per 100 metre row and about 20 pounds of seed was used for this purpose. In order to get the Crotalaria shade well established, selective weeding was done for about two months. This consisted in weeding carefully by hand the Crotalaria rows.

In poor sites, the Musa shade had to be substituted by a tree legume shade and 1.50 metre stakes of Erythrina poeppigiana, locally known as "Poró", were planted. This legume is characterized by its rather thin but large ovate leaves and almost thornless stem surface.

(b) Permanent Shade

Stakes of 1.00 metre length of Madero negro (Gliricidia sepium) were planted between the cacao rows. The stakes were spaced 3-4 metre apart and the distance between two Gliricidia rows was 8-10 metres. In this way the shade rows alternate with the cacao rows, leaving free access for future maintenance and harvesting operations. In the Gliricidia rows, 1.50 metre stakes of Erythrina poeppigiana were interplanted and spaced 12 metres apart. This Erythrina sp. is characterized by its smaller but darker-coloured leaves. The stem surface is almost free of thorns and the growth habit is more symmetrical with a smaller canopy with less tendency to breakage.

5. Planting Operations

Plant holes of 30 x 30 x 30 cm. or about 1 cubic foot were dug with a shovel. Nursery raised seedling rootstocks were re-wrapped in split banana stems but they were planted with the wrappers removed. Some 80 seedlings were planted per man day against 60 for rooted cuttings in the same time. The young cacao plants were loaded in a wheel chart in lots of 100-120 and they were transported by the tractor to the field. One laborer was in charge of actual planting, while two others assisted in distributing the plants over the sites and putting up artificial shade. This consisted of three 1.00 metre sticks of caña brava pointed at the base and tied together at the top in the form of a cone, with two or three fresh banana leaves wrapped around.

6. Maintenance

Throughout the experimental period, one special trained labourer was used all the time. The items as well as the cycles of operations are given below:

Items	Cycles per Year
Interrow weeding	4
Row weeding	6
Tillage and ringweeding	6
Mulching with banana trash	2
Spraying	12
Shade replacement	2

Interrow weeding was mostly done by hand using a machete or cutlass. For the first few months a 5 HP mechanical scythe was used.

Row weeding consisted of clean weeding a strip of 3 feet by hand on both sides of the cacao plants. It was observed that 3 rows of 50 metres each could be cleaned per man day. The utmost care was taken not to damage the cacao plants.

Tillage of the young cacao was done with a hoe of 8 inches width. First an area of one square metre around the cacao plant

was hoed and the soil was carefully loosened with the hoe. It was observed that, per man-hour, 12 plants could be hoed and tilled. When the plants were about a year old, earthing up was practiced. With a shovel, the soil around the plants was loosened for about a foot deep, and the rich surface soil of the interrows was thrown up. It was observed that four 50 metre rows of 12 plants each could be established per man-day. Earthing up was always preceded by row weeding.

While the plants were still young, a 3 gallon knapsack sprayer was used. The spray mixture consisted of a 2-2-50 Bordeaux mixture, to which 25 grams of Dieldrin (40 percent WP) was added. Per cycle, 10-15 gallons of spray mixture were used. As the plants grew in size, a 4-4-50 Bordeaux mixture was used. The plants were sprayed with a 300 gallon portable spray unit. The pressure at the spray nozzle was about 500 pounds per square inch. Per cycle, 150-200 gallons of mixture was used and about 6-10 man-hours were required per cycle. To control insect damage when necessary, especially the suppression of ants (Atta sp.), young cacao plants were hand-dusted with 2½ percent Dieldrin or Aldrin dust, in particular covering the terminal growth of the young seedlings.

Approaching the drier months of the year, prior to hoeing and tillage, banana trash was put around the cacao plants in order to conserve surface soil moisture. The trash was obtained either from thinning out the banana shade or from other sources.

The regulation of the shade consisted in the first months of opening up the Crotalaria hedges and pruning up the banana shade. All pruned material was left in the cacao rows to provide organic matter. At a later stage, the Erythrina shade was pruned and topped to adjust the shade to the size of the growing cacao.

7. Production of Planting Material

(a) Cacao cutting material of UFCo 650 and 667 was collected from the nearby cutting garden and rooted inside a closed type bin propagator. Sawdust was used as rooting medium and the cuttings were dipped in a 8.000 ppm indolbutyric acid hormone powder in order to stimulate rooting. After 4-5 weeks, only well-rooted plants were transplanted in sisalkraft paper wrappers which were filled with a soil sawdust medium. The cuttings were hardened in two weeks more and the plants were kept on a platform in the storage shed in order to complete their first flush. The rooting efficiency of the rooted cuttings in percentage is given below.

Time	Percentage (R.E.)
After 5 weeks	70
After 7 weeks	55
After 12 weeks	45

The regular maintenance until planting time was carried out and the required number of rooted cuttings was selected at planting time. The selection was based on vigour and low branching.

(b) Fresh seeds were extracted from ripe cacao pods of the green Amelonado type cacao (cacao corriente). The seeds were germinated in sawdust medium. After 4 weeks, the young plants were transplanted in cylinder shaped wrappers. These wrappers measured 30 cms. long and 8 cm. in diameter. The young plants in these wrappers were placed on specially constructed platforms with a lath shade of caña brava. The maintenance consisted of watering, fungicidal spraying and hand-dusting with 2½ percent Dieldrin WP, at intervals of 15 days, 5 grams of urea 46 percent were applied to each of the wrappers. By mid-December 1955, vigorous plants were selected and re-wrapped in split banana-pseudo stems. It was found that only 10 percent of the plants were lost or rejected. The mean height of the plants, measured

from the inside of the wrapper, was 40 cm. and the diameter 0.8 cm.

8. Budding Operations

These operations were done in three phases:

(a) Preparation of scion wood
(b) Actual budding of the stock plant and after-care
(c) Framing of the buddings

(a) Preparation of Scion Wood

About a month before budding time, scion wood was prepared in the cutting garden. In all cases, sucker wood of fan and chupon type were selected and, with a pruning shear, the leaves were removed, leaving a stub attached to the stem. It was observed that, in 3-4 weeks, these stubs fall off, leaving a well-healed scar tissue. The diameter of the budwood varied between 2.0 and 2.5 cm. The tissue of the scion wood was greyish-green and did not carry any flowers.

(b) Budding of the Stock Plants and After-Care

In this experiment the modified Forkert method (8) was used, also known as the inverted U-type budding method. With a sharp and clean budding knife, two straight vertical cuts and one horizontal cut, respectively 5 cm. and 2 cm., were made at about 20 cm. from the ground level. With the clean spatula of the knife, the bark was slightly but carefully lifted up. Holding the budwood stick in the left hand, two vertical and two horizontal cuts were made and the bud carefully lifted out and further quickly inserted behind the flap on the stock plant. Immediately after inserting the bud, the budded plant was tightly wrapped with 3/4 inch strips of paraffine wax-coated unbleached cotton cloth. In order to keep the buds dry, the windings of the wrappings overlapped

each other and a knot was made above the bud union. After 3 weeks, the cotton strips were removed and the plants were checked on "take". Plants were re-checked 15 days later and a slit about 40 cm. long was made in the stock plant 2 inches above the bud union and the whole plant bent over. As soon as the budding had formed its own foliage, the stock plant was decapitated about one inch above the bud union. It was necessary to keep the new sprout tied to the stock plant in the first months. This was done with the same paraffine coated cotton strip. Using this method, losses were reduced to a minimum and a symmetrical growth of the buddings was induced. At weekly or two weekly intervals, all extra and unwanted growth was rubbed off by hand. The method of budding which were applied for chupon and fan buddings is given below:

(i) Chupon Buddings. The bud was inserted on the north or south side of the plant, but only one bud was made per stock plant. The stock plant was slit up and bent over the direction opposite to the inserted bud.

(ii) Fan Buddings. Two methods were tried out. Two insertions were made on the north and south side of the stock plants either on the same level or at different levels. The other method consisted of making just one insertion per plant in the east or west side of the stock plant. In cutting back the sprout, new growth was induced from the same bud and in most cases symmetrical growth was obtained. In the latter case, only two sprouts were selected, each growing in opposite direction.

(c) Shaping of the Buddings

Three of the 5 jorquette branches of chupon buddings were selected to shape the plants. In some cases, pruning was early, as soon as the jorquette was formed; others

were pruned at a later stage.

The shaping of fan buddings was rather different. The ideal shape is a balanced limb V-shaped tree. About one metre of the limb was kept free of any growth. The terminal bud was cut off or pinched out in order to promote lateral growth or forking. The process of shaping fan buddings is a much longer process, since there is more variability in growth among this type of buddings.

9. Shaping of Rooted Fan Cuttings

This consisted firstly in selecting two to three primary limbs, preferably arising at or near ground level and showing a symmetrical growth. Secondly, pruning away all whippy branches and branchlets. All unwanted growths and all re-growths on these limbs were rubbed off regularly.

10. A number of stock plants failed at budding time or were not budded at all. These plants were either replaced by younger stock plant material or induced *in situ* to send off new suckers at ground level. The latter was effected by slitting up the stock plant at ground level and then bending over. The so induced suckers were moulded up but will be budded at a later time. This was also the case with the replacements.

Collection of Data

For the purpose of this paper, three kinds of data were regarded as important.

1. Cost data
2. Growth data
3. Survival data

1. Cost Data

The presentation of cost in this paper was expressed in the local currency (1 colón equivalent to 100 céntimos). The rate of exchange

was at US$1.00 for ¢6.60 (Costa Rica).

Cost data were collected from August 17, 1955 until August 31, 1957. The cost for manual labour, equipment and material was recorded on special sheets and further presented at monthly levels (Tables 22-25). Only actual labour earnings were recorded, leaving out extra costs, such as paid holidays, sick leave and supervision. The minimum wage at the farm, as well as for labour working in cacao plantations in the Atlantic zone, is ¢1.70 per man-hour or ¢13.60 per man-day of 8 hours. The labour working hours are from 6.00 AM till 3.00 PM with a break of one hour between 11.00 AM and 12.00. The highest wage which was paid in this experimental period amounted to ¢15.00 per man-day. The tractor fee at the farm is $1.00 or ¢6.60 per hour and consequently this was also used in this paper.

2. Growth Data of Cacao

The growth measurements were made with a tape measure and a metal caliper and all readings were recorded in centimeters.

The measurements for the young cacao plants varied with the plant which was measured and the period on which the reading was made.

The readings were made in the following periods:

Ending July 31, 1956
Ending October 31, 1956
Ending April 30, 1957
Ending July 31, 1957
Ending August 31, 1957

The readings of the four types of cacao plants are given below:

a. Rooted Cuttings. The vertical height of the plant and the diameter of the two main limbs;

b. Seedling Stock Plants. The diameter at 20 cm. from ground level and the vertical height. The diameter readings were continued after the buddings of the stock plants.

c. Chupon Buddings. The vertical growth of the limbs, the vertical height of the whole plant and the limb diameter.

d. Fan Buddings. The upright growth of the limbs, the corresponding limb diameter and the vertical height of the plant.

3. Survival Data

Records were kept of the number of supplies for the rooted cuttings and seedling stock plants. Records were also kept of the losses and successful unions of the buddings. In addition, the survival of buddings was recorded 3 and 6 months after the budding of the stock plants was initiated.

Analysis of Data

1. Cost Analysis

For the sake of convenience, the presentation of the cost analysis was divided into four distinct phases and are given below:

Phase	Subject	Period	No. Months
1	Land preparation and planting	Sept. 1, '55 - Jan. 31, '56	5
2	First growth period	Feb. 1'56 - Oct. 31, '56	9
3	Second growth period	Nov. 1'56 - April 30, '57	6
4	Third growth period	May 1'57 - Aug. 31, '57	4
		Total	24

The cost per phase, as well as accumulated cost, was calculated and presented. Since the experimental area was smaller than the area which was actually felled and cleared, the initial costs for land preparation were reduced to the equivalent of 1.15 hectares.

The breakdown of cost was presented at three levels: labour earnings, tractor fees and value of material. Also was included the number of man hours which correspond to the labour earnings.

2. Growth Analysis of Young Cacao

Since all cacao plants were given the same treatment and care, the analysis of growth readings until July 31, 1957 was limited to determine the total growth and the rate of growth. The total growth and the rate of growth (block mean) was presented in tabular form. The rate of growth was assessed by the substraction of the reading at any period from the succeeding one.

3. Survival Data

Ending August 31, 1957, the survival per treatment and per block was determined and the results presented in tabular form. The rooted fan cuttings, fan and chupon buddings were scored in two groups, which was based on visual appearance: healthy plants and plants with deficient and reduced growth.

IV EXPERIMENTAL RESULTS

Phase 1

The clearing of old cacao trees was started on August 18, 1955 and, by January 31, 1956, the experimental area, comprising 1.15 hectares, was completely cleared of former growth, re-shaded and replanted with young cacao.

In Table 22, the breakdown of cost ending January 31, 1956 is given by months. The expenditure covering a period of about 5 months amounted to ₡5.042.96. The operations which were involved required 190.6 man-days (1525 man-hours) and 165 tractor hours. In Table 22a, the breakdown of cost ending January 31, 1956 is given by operations. Land preparation alone comprised about 48 percent of the total cost and is given in Table 1.

TABLE 1

The breakdown of replanting cost, period ending January 31,'56

Items	Man-Days	Total cost in Colones	Total cost in per cent
Land preparation	81.2	2.412.26	47.8
Re-shading	61.5	1.082.13	21.5
Planting	47.9	1.548.57	30.7
Total	190.6	5.042.96	--

In this experiment, 384 cacao seedling rootstocks and 192 cacao rooted fan cuttings were planted or, in other words, in the proportion of 2 to 1. In Table 2, the breakdown of the value of cacao planting material, ending January 31, 1956, is given.

TABLE 2

The value of cacao plant material, period ending January 31,'56

Items	Field Cost ¢	Value nursery plants ¢	Total Cost ¢
Cacao seedlings	2.913.97	288.60	3.201.97
Cacao rooted cuttings	1.456.99	384.00	2.840.99
Total	4.370.96	672.00	5.042.96

The overall cost per young cacao planted, ending January, 1956, was ¢8.75. The values per rooted cutting and per seedling are presented in Table 3.

TABLE 3

The value per cacao plant at two levels

Items	Value planted cacao in Colones	Value nursery plant in Colones
Cacao seedlings	8.34	0.75
Cacao rooted cuttings	9.59	2.00

Land Preparation

The clearing of old cacao trees, including stacking the cut up trees, was terminated by September 20, 1955. The weather conditions in the corresponding period were very favourable, sunny and dry during the day and with little rainfall. An estimated 515 cacao trees were cleared and this required an expense of ¢1.554.53. The cost per cacao tree, cut up and stacked, was thus ¢3.02. The cacao clearing operations required in this area of 1.15 hectares 44.8 man-days, or an efficiency of 11.5 cacao trees per man-day.

The experimental area was cleared of shade trees, disced and lined up by October 20, 1955. This required an expense of ¢857.73 and 36.5

man-days.

The weather conditions ending October 20, 1957 at weekly levels are given below:

Period	Rainfall		Total solar radiation in hours
	Inches	Days	
Week ending Aug. 23	0.52	2	27.2
" " " 29	0.00	-	37.2
" " Sept. 4	0.65	3	25.2
" " " 10	0.79	2	37.1
" " " 16	1.78	4	27.5
" " " 22	0.43	2	36.2
Total	4.17	13	191.0

In Table 22b, the breakdown of land preparation per item is given. The expense for land preparation at two levels is given in Table 4.

TABLE 4

The cost of land preparation at two levels

Items	Expenditure		Man-days	Cost per man-day in ¢
	¢	%		
Clearing of old cacao	1.554.53	64	44.8	34.70
Other operations	857.73	36	36.4	23.56
Total	2.412.26	-	81.2	

Reshading

The planting of the temporary shade was initiated in the third week of October and completed by November 1st, 1955. The germination of the Crotalaria seed was excellent and, in about two months after seeding, the young plants reached an average height of 3 feet. In some rows of block E and F bordering the middle road, the young

plants appeared to be less healthy and showed a restricted growth; the soil in these spots is rather stony and the texture of the soil is different from that of the rest of the area. The root system of the Crotalaria plants growing there showed a rather curved taproot development. In the rest of the area, except for a few bad spots, the growth of the Crotalaria shade was vigorous and uniform. The growth of the banana shade was much slower and irregular in the beginning. In the same sites where the Crotalaria showed a restricted growth, the banana shade failed completely. It was further observed that part of the failures were also due to root infestation with the common banana root borer, (Cosmopolytus sordidus G.).

Since the banana shade and the Crotalaria shade were planted at the same time, it was decided to split up the initial maintenance cost equally over the two items. The establishment of lateral shade, ending January 31, 1956, required 61.5 man-days and amounted to ¢1.086.13. In this cost is included the amount of ¢113.34 for replacing the shade with stakes of Erythrina poeppigiana. The breakdown of reshading costs is given in Table 22c.

Planting

In the second week of December 1955, planting operations were begun and terminated by December 25, 1955. This involved digging plant holes, clean weeding of the cacao rows and interrow weeding. Actual planting of the cacao was commenced on December 28, 1955 and completed by January 14, 1956. The weather conditions during planting operations were very favourable with overcast skies and light drizzle during the day and rain at night. The weather conditions during actual planting are given below:

Period	Rainfall		Solar radiation in hours
	Inches	Days	
Dec. 28 - Jan. 14	17.63	18	20.6

The expense for planting the young cacao and after-care, covering a period of approximately 7 weeks, amounted to ¢1,548.57, of which ¢672.00 covered the cost of the cacao plant material. In the same period, 47.9 man-days and 14 tractor hours were required to complete the operations. The breakdown of planting cost is given in Table 22d.

Phase 2

The expenditure covering this period of nine months amounted to ¢2.436.94. The operation in the same period required 132.9 man-days (1063 man-hours) and 68 tractor hours. "Tractor hours" refer to the use of the mechanical scythe. In Table 23, the expenditure ending October 31, 1956, is presented at monthly levels. In Table 23a the breakdown of cost ending October 31, 1956 is given at three levels.

The accumulated cost, for the period ending October 31, 1956, 14 months after the experiment was started, amounted to ¢7.479.90. The investment per cacao plant was thus ¢12.98, an increase of 48 percent as compared with the previous phase.

In May, June and August 1956, 26 rooted fan cuttings and 61 seedling rootstocks were replaced. In all cases the plants which were replaced showed a restricted top growth. Moreover, most of the replaced seedlings showed a curved and bended taproot. The survival after 9 months of growth in the field was thus 87 percent for the rooted fan cuttings, against 84 percent for the seedling rootstocks. The growth performance of the seedling rootstocks for the period ending October 31, 1956, is given in Table 5. The means for plant height and stem diameter was 102.1 cm. and 1.80 cm., respectively.

TABLE 5

Growth performance of seedling stocks at two levels, period ending October 31, 1957 *

Block (64 plants)	Mean per Plant in cm.	Mean diameter in cm.
A	100.9	1.75
B	106.7	1.70
C	102.6	1.90
D	95.8	1.80
E	100.8	1.75
F	100.5	1.85
Total	612.3	10.75
Mean	102.1	1.80

* Nine months of growth in the field.

After nine months of growth in the field, 190 seedlings had a stem diameter of 2.0 cm. or more, representing about 50 percent of the total number of seedlings. The stem diameter of the seedlings at three levels is given in Table 6.

TABLE 6

The stem diameter of seedling plants in three classes, period ending October 31, 1957

Class in cm.	No. Plants	Percentage
1.0 - 1.5	77	20.0
1.6 - 1.9	117	30.8
2.0 and more	190	49.2
Total	384	--

The extremes of stem diameter, for the period ending October 31, 1956, were 1.0 cm. and 2.3 cm. The distribution is represented in Fig. 2 and 3. Assuming a stem diameter of 0.60 cm. of the seedlings

at planting time, the mean growth rate in nine months was thus 1.20 cm. The means for vertical growth and the diameter of the main limb of the rooted fan cuttings was 64.7 cm. and 1.36 cm. respectively. The number of plants which exceeded a limb diameter of 1.50 cm. amounted to 41 percent. In Table 7, the growth performance of the rooted fan cuttings per block is presented.

TABLE 7

Growth performance of the rooted fan cuttings, period ending October 31, 1956 ‡‡

Blocks (32 plants)	Height in cm.	Diameter ‡ limb in cm.	Diam. 1.5 cm or more	
			No.plants	Percent
A	60.0	1.20	2	6
B	60.6	1.35	10	31
C	59.5	1.35	13	41
D	59.5	1.35	18	56
E	73.8	1.45	15	47
F	73.4	1.45	20	62
Total	386.9	81.5	78	--
Mean	64.7	1.36	13.0	41

‡ The reading of one limb diameter per plant was represented.
‡‡ Nine months of growth in the field.

Phase 3

The expenditure of phase 3, covering the period between November 1, 1956 and April 30, 1957, amounted to ₵1,193.00, and this period required 81 man-days (648 man-hours). The expenditure cost and accumulated cost for the period ending April 30, 1957, is represented in Table 8.

TABLE 8

Cost and accumulated cost, period ending April 30, 1957

Phase	Total Expenditure £	Cost per plant £	Increase investment in percentage
1	5.042.96	8.75	--
2	2.436.94	4.23	48.3
3	1.193.00	2.07	23.6
Total	8.672.90	15.05	--

In Table 24, the breakdown of expenditure of Phase 3 is given at monthly levels. In Table 24a, the cost per item is presented.

Early in November, 1956, the stock plants which had a diameter of 2.0 cm. or more were budded. According to Table 6, these represented about 50 percent of the total number of stock plants. Owing to unexpected heavy rainfall, the "take" of the buddings was very low and consequently only a very small number of growing buds was obtained. The weather conditions before, during and after the budding period are given below:

Item	Period	Rainfall inches	Rainless days ⁂	Solar radiation in hours
Before budding	1- 6 Nov.	5.90	4	24.7
During budding	7-18 Nov.	2.99	7	41.9
After budding	19-30 Nov.	5.88	7	25.4

⁂ 6:00 AM. - 6:00 PM.

TABLE 9

The results of budding at two levels, grown over a period of 3 months

Blocks	No. Stock Plants	Chupon Buddings			Fan Buddings		
		"Take"	Alive	Alive*	"Take"	Alive	Alive*
A	32	21	13	-	26	22	-
B	32	27	21	-	30	26	-
C	32	30	27	-	31	27	-
D	32	30	28	-	30	29	-
E	32	27	22	-	28	20	-
F	32	29	23	-	32	23	-
Total	192	164	134	69.3	177	147	76.5

* Percentage plants alive

By January 20, 1957, the budding and re-budding of the stock plants were resumed. Assuming an average radial growth of the seedling of 0.20 cm. per month, most of the stock plants in the second group (see Table 6) had reached by this time a diameter of 2.0 cm. In February, all remaining but healthy stock plants were budded. The "take" for the chupon buddings was 85 percent against 92½ percent for the fan buddings. However, the final results, thus about 4 months after budding was done, showed an efficiency of 69.3 percent for the chupon buddings and 76.6 percent for the fan buddings (Table 9). The growth performance of the young buddings, for the period ending April 30, 1957, is given below:

Type of Plant	Limb Diameter	Height of Plant
Chupon buddings	1.18 cm	55.5 cm
Fan buddings	1.02 "	53.3 "

The average diameter of the stock plants for the period ending April 30, 1957, was 3.13 cm. In nine months of growth, the seedlings averaged 1.80 cm. (See Table 5). The rate of growth in 6

months was thus 1.33 cm., representing an increment of 0.22 cm. per month. The growth performance of the stock plants, chupon and fan buddings is presented in Table 10.

TABLE 10

Growth performance of budded plants at two levels, period ending April 30, 1957

Block (32 plants)	Diam. stock in cm.	Chupon Buddings		Diam. stock in cm.	Fan Buddings	
		Limb diam. in cm.	Height in cm.		Limb diam. in cm. *	Height in cm.
A	3.1	1.20	48	2.9	1.05	51
B	3.1	1.30	62	3.1	1.10	50
C	3.3	1.15	62	3.2	1.05	57
D	3.3	0.95	48	3.0	0.95	60
E	3.2	1.10	49	3.3	0.90	42
F	3.0	1.40	64	3.1	1.10	60
Total	19.0	7.10	333	18.6	6.15	320
Mean	3.17	1.18	55.5	3.10	1.02	53.3

* Diameter of one limb per plant.

The average diameter of the rooted fan cuttings, for the period ending April 30, 1957, was 1.79 cm., representing a growth increment of 0.43 cm. in six months (See Table 7). The increment per month was thus 0.07 cm. The mean height of the rooted cuttings was 98.8 cm., representing an increment of 34.1 cm. in six months (See Table 7), and hence an increment per month of 5.7 cm.

After 15 months of field performance, 60 rooted cuttings, or 31 percent, had a limb diameter of 2.0 cm. or more. The maximum limb diameter per plant at this time was 2.7 cm. The growth performance of the rooted cuttings, for the period ending April 30, 1957, is presented in Table 11.

TABLE 11

Growth performance rooted fan cuttings, period ending April 30,'57

Block (32 plants)	Height in cm.	Diam.limb in cm.	Limb diam. 2.0 cm. or more	
			Number plants	Percent
A	93.5	1.68	6	19
B	99.7	1.87	15	49
C	96.9	1.65	5	16
D	94.7	1.81	11	34
E	101.2	1.82	11	34
F	106.9	1.94	12	37
Total	592.9	10.77	60	-
Mean	98.8	1.79	10	31.2

Phase 4

The expenditure covering the period between May and August 31, 1957, amounted to ¢1.202.63 and this period of 4 months required 77.2 man-days (618 man-hours). The expenditure, cost and accumulated cost, for the period ending August 31, 1957, is presented in Table 12.

TABLE 12

Cost and accumulated cost, period ending August 31, 1957

Phase	Total Cost ¢	Cost per Plant ¢
1	5.042.96	8.75
2	2.436.94	4.23
3	1.193.00	2.07
4	1.202.63	2.07
Total	9.875.53	17.44

In Table 25, the breakdown of cost of Phase 4 is given at monthly levels. In Table 25a, the breakdown of the operation cost, as well as the number of cycles of operation, are presented.

Ending July 31, 1957, the mean height of the fan buddings was 110 cm. against 112 cm. for the chupon buddings. The differences were more accentuated when comparing the limb diameter of the two types of vegetative propagation. The limb diameter of the chupon buddings averaged 2.40 cm. against 1.97 cm. for the buddings, representing a difference of 0.43 cm. The growth performance per block is presented in Table 13.

TABLE 13

The growth performance of chupon and fan buddings, ending July 31st, 1957

Block	Stock diam. cm.	Chupon Buddings limb diam. in cm.	Chupon Buddings height in cm.	Stock diam. cm.	Fan Buddings limb diam. in cm.	Fan Buddings height in cm.
A	3.80	2.40	118	3.50	1.95	114
B	3.70	2.20	94	3.55	2.00	112
C	3.75	2.55	129	3.90	2.00	113
D	3.70	1.90	82	3.45	1.85	90
E	3.80	2.50	114	3.75	1.95	112
F	3.75	2.70	136	3.60	2.10	120
Total	22.50	14.25	673	21.75	11.85	661
Mean	3.75	2.37	112	3.62	1.98	110

The rate of growth in cm. of the fan and the chupon buddings in these 3 months is given below:

Item	Stock diam.	Limb diam.	Limb length
Chupon buddings	0.57 cm.	1.19 cm.	18.8 cm.
Fan buddings	0.52 "	0.96 "	47.7 "

The extremes of the growth rate in cm. in the six blocks are given below:

Item	Chupon Buddings	Fan Buddings
Stock diam.	0.35 - 0.75 cm.	0.40 - 0.70 cm.
Limb diam.	0.90 - 1.40 "	0.80 - 1.10 "
Limb length	14 - 24 "	32 - 60 "

The mean limb diameter and the height of the rooted cuttings are given below, for the period ending July 31, 1957, after 18 months of growth. For the limb diameter two reading per plant were made, since shaping of rooted fan cutting was based on a two limb plant.

Limb diameter (a)	2.27 cm.
Limb diameter (b)	1.85 "
Mean height of rooted cuttings	132 "

The growth performance of the rooted cuttings at block levels is given in Table 14.

TABLE 14

Growth performance of rooted cuttings, period ending July 31, 1957

Block (32 plants)	Scion diam. in cm.	Scion diam. in cm.	Height in cm.
A	2.20	1.80	133.1
B	2.40	1.95	137.6
C	2.20	1.70	128.3
D	2.20	1.80	123.0
E	2.30	1.90	125.0
F	2.30	1.95	145.0
Total	13.60	11.10	792.0
Mean	2.27	1.85	132.0

The extremes of growth rate in cm. of rooted cuttings in the six blocks are given below:

Item	Mean	Extremes
Limb diameter	0.48 cm.	0.30 - 0.65 cm.
Height of plant	33.2 cm.	12 - 44 cm.

For the purpose of this paper, the experiment was concluded on August 31, 1957. Except for a proper permanent shade, drainage system and the budding of "supplies", the area was re-established in 24 months after the first old cacao trees had been removed.

The efficiency of the nursery system (rooted fan cuttings) and the field method (buddings) is given below:

Type of Plants	No. planted	No. supplies	Efficiency in percent
Rooted fan cuttings	192	26	86.5
Chupon buddings	192 *	--	69.3
Fan buddings	192 *	--	77.4

* Stock plants

The above shows that about 14 percent of the rooted cuttings did not survive in the early stages and about 27 percent of the stock plants failed to give a bud-union. The results of the fan buddings were slightly better; this might probably be due to the fact that part of the fan buddings were twin-budded.

The cost of operation, including the time required (man-days), and the cycles of operations, are presented in Table 26. In 19 months of maintenance, 52 percent of the cost alone was expended on weed control and tillage in the cacao lines. The cycles for

the latter operations were once every two months. In the last phase, some of the buddings were mechanically damaged, but re-growth was quite rapid.

The scoring of the buddings and the rooted cuttings into two groups representing the percentage of vigorous growing plants is given below:

Type of Plant	No. Plants	% vigorous
Chupon buddings	134	65.8
Fan buddings	147	63.2
Rooted cuttings	192	71.3

Such a scoring was done visually and was based on vigour, healthy foliage and symmetrical growth. These vigorous growing plants comprised plants having a height of 1.30 mt. or more, with a limb diameter of exceeding 2.5 cm. for the chupon buddings and single limb fan buddings and 4.0 cm. or more for the rooted fan cuttings and two-limb fan buddings. The presentation at block levels is given in Tables 15a and 15b.

TABLE 15a

Budding results in the six blocks, grown over a period of 7 months

Block	Chupon Buddings			Fan Buddings		
	Alive	Good	% Good	Alive	Good	% Good
A	13	9	-	22	15	-
B	21	11	-	26	17	-
C	27	22	-	27	20	-
D	28	13	-	29	11	-
E	22	16	-	20	17	-
F	23	17	-	23	13	-
Total	134	88	65.8	147	93	63.2

TABLE 15b

The results from rooted fan cuttings in the six blocks grown over a period of 19 months

Block	Number of Plants		
	Alive	Good	% Good
A	32	24	-
B	32	23	-
C	32	21	-
D	32	19	-
E	32	23	-
F	32	27	-
Total	192	137	71.3

V DISCUSSION

Phase 1

The Removal of Old Cacao Trees

The high cost of clearing the old cacao trees, comprising almost 64 percent of the total cost for land preparation (Table 4), might lead to the belief that the methods used in this experiment were not efficient. This was indeed the case, since extra expenses were involved in (a) transporting the old cacao trees and (b) stacking the cut-up trees outside the experimental area. Under normal conditions, these two operations, as mentioned above, are not done; the old cacao trees are usually clear-felled at ground level, cut up and the trash is spread out in straight rows in the same area.

Using mechanical force, an estimated 80 old cacao trees can be lifted out with their principal roots attached, per day. The tractor fee per day is ¢52.80 and the labor fees (team of 2 laborers) are ¢28.80 per day. The cost per tree removed, using mechanical force, would thus be (81.60 ÷ 80) ¢1.02, of which ¢0.66 is the share for the use of the tractor. In this experiment, mechanical clearing including the transport of old cacao trees to the stacking place, cost ¢2.02 per tree. Hence the transport share was ¢1.00 per tree which equals about 33 percent of the total cost per tree removed, cut up and stacked.

Omitting in a future experiment the items for transport and stacking, and allowing ¢0.60 per tree for contract cutting up, the cost per tree removed and cut up would amount to (1.02 + 0.60) = ¢1.62. The labor efficiency would be 32.5 trees per man-day, when 25 trees for cutting up and 40 trees for mechanical removal per man-day is allowed. In this experiment, the labor efficiency was 11.5 cacao trees per man-day which clearly indicates that the method of complete clearing as practiced

here, was economically not justified. The main reasons of following the method of complete clearing in this experiment was to avoid any possible adverse effect of old cacao trash on the growth and survival rate of the new planted cacao. Normally the new cacao is planted at least one year after the area is cleared of former growth. In this experiment, planting was speeded up in order to gain time.

In the finca "La Lola", the contract price per old cacao tree, clear felled and cut up by hand, amounts to ¢1.50 with a labor efficiency of 10 trees per man-day. It is obvious that, when a tractor is available, the clearing of cacao trees using mechanical force is economically justified and, at the same time, far more efficient. Instead of cutting up by hand, a hand-operated powered saw may be used. Such a saw can be purchased for US$200.00 and a charge of US$2.00 or ¢13.20 per day may be allowed. However, trained labor should be employed in order to allow a high efficiency per man-day.

In this experiment, the clearing of old cacao trees required an estimated 17.9 man-days per acre against 18.0 man-days in Grenada for the same operation (26). Assuming 200 trees per acre, and using the method as suggested above of 32.5 trees per man-day, the clearing operation would require roughly 6.0 man-days per acre. The question of effective labor use in this respect should be carefully considered, since less labor means lower overhead expense for social security and housing.

Temporary Shading

Since the area was completely exposed, a quick cover of temporary shade was necessary. This was achieved by planting Crotalaria and banana shade at the same time. The Crotalaria bush is a fast grower, but the stems are very brittle. Despite the heavy rains and winds at the end of the year, a hedge shade of 1.50 metre high was obtained four months after planting the

seed. Most of the cost for establishing a hedge shade was spent in the first months after planting the seed. Once the Crotalaria plants were tall enough, selected weeding in the Crotalaria rows was omitted. Assuming an effective use of the Crotalaria shade for 9 months, the cost per young cacao of ¢0.85 for this shade does not seem to be expensive. Besides the shade factor, other advantages of the hedge shade have to be taken into account, such as improving soil fertility and structure, and the protection for the young cacao against drying out. However, in order to overcome the brittleness of the Crotalaria, and stretching out the effective use of the hedge shade, an admixture in the ratio of 40/60 can be used of Tephrosia candida and Crotalaria anagyroides (8). The Tephrosia seems to grow well in "La Lola" and, in six months, a hedge shade 1.50 metres tall was obtained. The optimum use of Tephrosia hedge shade is about 18 months, or twice as long as Crotalaria.

The planting of the banana shade in the cacao rows was a bad practice. Originally it was planned to establish this shade between the cacao rows and spaced three metres apart. In this way, weed growth could be suppressed quicker. However, this view was rejected by the Graduate Committee on the ground that it would not be possible to use the mechanical scythe for the purpose of weed control. The banana shade required an expense of ¢487.34, or approximately ¢0.85 per banana plant. The market price for this banana variety is ¢0.80 per bunch; the cost of harvesting and transport to the market alone exceeds considerably the indicated market price. Hence, the cultivation of such a banana variety, as a source of income under conditions in this experiment, was not possible. In this respect the stress was laid on shade and as a source of organic mulch.

The planting of temporary shade required an expense of ¢1.082.13, or roughly ¢1.90 per cacao plant. The planting of stakes of a Erythrina sp. would possibly be better economics.

The merits of an Erythrina shade are a quick growth and a rich source of organic matter. In addition, these rather deep rooted plants may improve the internal drainage of the area and raise the nutritional level of the surface soil. In this experiment, 61.5 man-days or 34.6 man-days per acre, were required for re-shading, against 17.0 man-days per acre in Grenada (26).

The Production and Planting of Young Cacao

The planting and after-care of the young cacao, comprising a period of about two months, required an expense of ¢1.52 per plant. When compared with the expenditure for other operations, the expense for planting is rather low. A comparison of the cost input is given below:

Items	Investment per Young Cacao In ¢	In %
Land preparation	4.18	55
Re-shading	1.88	25
Planting	1.52	20
Total	7.58	
Value plant material	1.17	
Total	8.75	

In this experiment, the young cacao was grown in wrappers of asphalt paper. Such wrappers are not only expensive but, when plants are kept too long, the soil in the wrappers tends to become hard and consequently the young plants seem to suffer from pot-boundness. However, seedlings can be successfully raised in perforated tubes of polyethylene (plastic). The cost per tube is ¢0.18 and such tubes may have an optimum use of six months. This material is strong and the soil in the tube remains friable and well aerated. Consequently pot-boundness can be avoided and the planting of six months old plants can be done successfully. In this experiment, the seedling rootstocks were about 3 months

old when they were planted in the field. The traditional method of planting seed in bamboo joints or in nursery beds might be cheaper, but the percentage of well developed plants might also be rather low.

Phase 2

The After-Care of the Young Cacao

The re-planting of the experimental area was speeded up by planting the young cacao at almost the end of the wetter period. In this way, about 4 months were gained, since the next wet period usually starts in May. Under normal conditions, planting is done in the beginning of a wet period. The approach used in this experiment greatly influenced the system of operation, as well as the initial expenditure for re-planting.

The high survival, especially of the rooted fan cuttings, is noteworthy. The Compañía Bananera in Costa Rica abandoned the planting of rooted fan cuttings in the Atlantic zone of the country a few years ago, owing to high mortality. The expense per plant in nine months after planting the young cacao was ¢4.23, of which ¢2.08 was the share for row weeding, hoeing and tillage. It is quite obvious that, when sufficient maintenance is given, a high survival may be obtained. In this experiment, the system of clean weeding in the row was followed. The cost per 50 metre row was ¢4.00, representing an expense of about ¢200.00 per hectare per cycle. In addition, hoeing and tillage were done at 60-day intervals. The cost per plant per cycle for clean weeding in the row, including hoeing and tillage, was roughly ¢0.50, or ¢0.25 per month. In shaded young plantings, ring weeding is only done at 30-day intervals. The cost per cycle is only ¢0.08 or, in other words, 33 percent of the experiment total. The adjustment of the temporary shade, which was regarded as necessary, also contributed to a faster growth of the weeds. The cycles for brushing

the interrows were kept to a minimum. The weeds were left to grow with the idea to use these interrows as a control to check run-off in the heavy rainy season.

Although the growth of the young cacao was fast and rather uniform, except in poor soil sites, it is unlikely that such expensive weeding can be recommended in young plantings. The presence of the banana plants in the cacao rows was not effective in checking the weed growth in the rows. Besides, with the maturity of the banana plants, a root competition with the young cacao was observed. On the other hand, the Poró shade (Erythrina poeppigiana), which was also planted in the rows, gave a denser shade and consequently weed growth was rather suppressed. When replanting is practiced, it is likely that the Erythrina shade established from stakes, would mean a considerable saving in weeding costs. In addition, in a short time, an abundant amount of leaf litter is formed owing to the almost continuous leaf fall and slow rate of decomposition. It would possibly be worthwhile to try out, in a future experiment, the planting of young cacao, using various types of shade. In this experiment, the symmetrical growth of the young cacao was stressed. The choice of a proper shade tree, allowing optimum growth of the young cacao, and giving a quick soil cover, is to be considered in future experiments.

The rather high cost for weed control, either in the row or in the interrows, might raise the question as to whether the use of mechanical or chemical weed control might be justified. Mechanical weed control in the interrows was not satisfactory. The mechanical scythe gave an efficiency of 20, fifty metre interrows per day. However, due to the heat produced by the motor, a cooling off period was required. In sloping and undulating terrain, the operations were quite difficult and tiring. The cost per cycle of mechanical clearing is given in page 53.

Labor share - 4 man-days	¢ 54.40
Equipment share	48.00
Total	¢ 102.40

The fee for the use of this mechanical scythe was based on ¢1.50 per hour, or ¢12.00 per day. Even with a lower fee, the cost for hand weeding is still more economical.

The effect of chemical weed killers was not tried out in this experiment, as little is known about the use of herbicides in young cacao plantings. Since most of the cost was spent for row weeding, the use of herbicides, which probably will be applied with a 3-gallon knapsack sprayer, may possibly cut down maintenance cost. The effect on plant growth, however, should be closely observed.

At the time of "supplying", mottling was observed in the plant holes. The development of a bent taproot in these spots gave also a strong urge to commence the draining of the experimental area. It was observed in the same farm that many young seedlings which were grown on nursery beds had a bent taproot. It is possible that poor internal drainage may cause this curving. It was proposed to make sufficient drains at clearing time; unfortunately, this had not been done at the time of presenting this project, it being thought to be unnecessary because of the fact that the area has a slight slope and a depression to the north, thus acting as a kind of natural drainage.

Phase 3

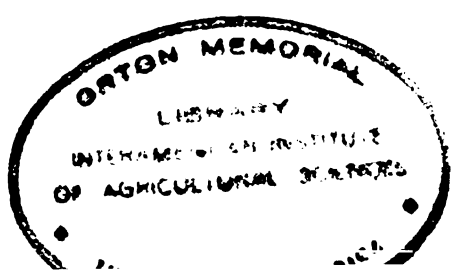
Budding at Stake

The idea of budding so late in the year was to gain time in order to get the budded plants established earlier. However, the first budding experiment failed almost completely. Despite excess of soil moisture in the wet period from November onwards, radial

growth of the stock plants seemed to have continued. While in November 1956 about 50 percent of the stock plants had a stem diameter of 2 cm. or more, by the end of January 1957, 3 months later, 80 percent of the plants had a stem diameter of 2.5 cm. The poor results in budding might also be due to the lack of a "flush" period. The results of budding in January and February 1957 were better. Budding was done at the end of the wet season, exactly one year after the seedling stocks were planted and at the beginning of a new major "flush" period.

It was observed that, between the first and the second readings (Table 9), about 15 percent of the buds were lost. Judging from the data in the same table, it is evident that the efficiency of budding was roughly 70 percent against 50 percent for the rooted fan cuttings. With better care and attention, the efficiency at planting time of the rooted fan cuttings might be increased to about 70 percent. Unfortunately, it was not possible to achieve a higher efficiency for the rooted fan cuttings in the finca "La Lola".

Instead of budding at the end of the rainy season, budding may be done in April, just before the onset of the new rainy season. However, a further postponement of the budding operations could not be risked, in view of the original target date of June 1957. It was observed that the critical period in budding at stake is about two months when the new foliage is tender and protection with a fungicide is difficult. The few buds which survived in the first budding trials showed that, despite the wet period, a new and healthy plant was obtained in just 3 months. This seems to indicate the positive effect of the stock on scion growth. In about three months after the buds were inserted, a limb growth of 50 cm. length was obtained (Table 10). At that time, the new growths had about 25 fully matured leaves. In most cases, the chupon buddingshad already formed a jorquette.



The bent part of the stock plant above the bud union was not decapitated deliberately. In Table 10, it was stated that the average stock diameter was 3.17 cm. for the chupon buddings against 3.10 cm. for the fan buddings. Assuming a stock diameter of 2.50 cm. at budding time, there was a growth increase of about 0.60 cm. in just three months, or 0.20 cm. per month. Hence the system of retaining the upper part of the stock plant apparently had no negative effect on the growth of the new bud.

Rate of Growth

The rate of radial growth of the stock plants and buddings is given below:

Type of Plant	Diam. in cm.	Time in months	Rate of growth per month in cm.
Stock plants	3.17	15	0.21
Buddings	1.18	3	0.39

It is obvious that an increase in growth of the bud will decrease the development of the stock plant and decapitating the stock plant at budding time or afterwards, as suggested by so many workers, is apparently bad practice. A further increase in diameter of the stock plant should never be regarded as a nuisance, but rather as an advantage.

Comparing the rate of radial growth in cm. for the three types of plants for the period ending April 30, 1957, the following information was obtained.

Type of Plants	Time in months	Rate of growth in cm.	
		Total	Per Month
Chupon buddings	3	1.18	0.39
Fan buddings	3	1.02	0.34
Fan cuttings	6	0.43	0.07

Even assuming a three limb fan cutting, the rate of growth per month would still be half of that of the buddings. In just 15 months of field-performance, the limb diameter of the rooted cuttings was 1.79 cm., or 0.12 cm. per month. Ending October 31, 1956, 9 months after planting, the limb diameter was 1.36 cm., representing an average growth of 0.15 cm. per month (Table 11). These data seem to show that, after October 31, 1956, there was a decrease in growth rate. This decrease could not have been attributed to pruning, since pruning was done after April 30, 1957. An explanation of this phenomenon is difficult to find, since the buddings and the stock plants had shown a good growth during the same period.

Phase 4

Growth and Cost Analyses of the Rooted Cuttings

In this experiment, the rooted cuttings were pruned, starting in May 1957, after 15 months of field performance. With such a pruning or shaping as it usually referred to, it was aimed to obtain a proper frame on which the fruit may be borne. Little is known about proper shaping of rooted fan cuttings and consequently such plants are usually left to grow until cropping time. In future experiments, it would be very interesting to study the effect of shaping on growth and yield performance. Besides the age of the plants and the period of pruning, the results obtained in relation to the weather conditions, should be considered. In the three months which elapsed after pruning was initiated in this experiment, the growth rate of the main limb averaged 0.48 cm., or 0.16 cm. per month. In the previous period (Phase 3),

the growth increment was 0.43 cm. or 0.07 cm. per month. It is not likely that with such data on hand, as explained above, pruning would retard the growth performance of young cacao cuttings.

Another important item was the anchorage of the rooted fan cuttings. It was observed that about 50 percent of the plants were loosely anchored or showed signs of falling over. The latter is usually referred to "tipping over". In some countries, it is recommended to stake young cacao cuttings at planting time in order to induce a symmetrical growth and to get the plants well anchored in the soil (24). In this experiment, all plants, including the budded seedlings, were earthed up. This required an extra expense of ¢0.30 per plant per cycle. The effect of earthing up, which of course ought to be repeated periodically, should be closely observed. In Costa Rica, coffee is grown on cambered beds and it may be interesting to study the growth of rooted cacao cuttings in relation to intensive cacao cultivation in this country. In some sites in this experiment, planted to rooted cuttings and growing under Poró shade (Erythrina poeppigiana), it was observed that such plants were generally well anchored and were also showing a vigorous growth. It is possible that such shade, planted close to the cacao (midway between two cacao plants in the cacao rows), may improve the physical status of wet soils, thus facilitating a better root development for the young cacao.

Ending August 31, 1957, after 19 months of field performance, 71 percent of the rooted cuttings were growing vigorously. Such plants averaged a limb diameter of 2.5 cm. (one reading per plant) and a corresponding vertical height of 1.30 meter or more. Assuming a monthly growth rate of 0.15 cm., such plants should have a limb diameter of 5 cm. or 2 inches in a year's time. Since most of the plants are already flowering and some even have set fruit, the first good pods might be expected by July 1958. Considering a market price US$0.30 per pound, the investment per rooted cutting until the first cropping year will be equivalent to roughly 12 pounds of dry cacao

or 80 ripe pods. Assuming 240 plants per acre, 2880 pounds of dry cacao must be produced to counter balance the investment per acre. The future cropping years will clearly indicate when these returns can be expected for this experiment.

Growth and Cost Analyses of the Buddings

In seven months after budding at stake, about 65 percent of the buddings (chupon and fan buddings) were growing vigorously. Such plants had a limb diameter of 2.5 cm. or more, with a corresponding vertical height of 1.30 meter. At budding time, the stock plants averaged a diameter of 2.5 cm. These results, as mentioned above, clearly indicate that good results in budding at stake can be expected. The rate of growth of the main limb in three months was 1.06 cm. or, in other words, 0.35 cm. per month. Assuming a monthly growth rate of 0.20 cm. most of the plants will attain a limb diameter of 5 cm. or 2 inches in a year's time. It is likely that the first good pods may be harvested by then, which means 1½ year after the buddings were made. In all, the plants will be then 3 years old.

It is too early to state which type of budding would be preferred. However, in this experiment, the chupon buddings showed a rather uniform growth; only a small number of plants formed a jorquette at a very low level. This may possibly be attributed to the use of budwood which was obtained from productive rooted fan cuttings. Besides, when budded with chupon material, fan buddings were obtained in some cases. Under normal conditions, budwood is prepared in a budwood garden. Since such was not available in the finca "La Lola", and its establishment would require at least a period of two years, budwood was prepared from productive rooted cuttings in the clonal cutting garden at the farm. The system of budding the stock plants on both sides (double budded fan buddings) gave promising results. Apparently, there was no remarkable difference in diameter growth between the single and double budded fan buddings. The buddings were made at almost the same time.

The chupon buddings, on the other hand, showed a faster radial growth. The advantage of a well-balanced tree will become more marked when the plants mature and commence to bear fruit. The shaping of the fan type plants which showed a symmetrical growth was rather simple. Tying up the young buds in the beginning had very little effect on upright growth. It was observed that the stock plant was in most cases responsible for a rapid and symmetrical growth of the inserted bud. In sites where the growth conditions for the stock plants were less favourable, a whippy and a more horizontal growth was observed. From the results of the method of budding at stake, it seems that the preparation of the plant sites before the stock plants are planted should be given the utmost attention.

Since budding at stake was not carried out within a definite time, but rather stretched out, and three different types of buddings were used, the total cost of budding was not included in the cost assessment. However, budding cost may easily be determined. In one man-hour, 30 stock plants can be single-budded, or 15 plants double-budded. Per man-day, for a laborer working 4 to 5 hours, 120 plants may easily be single budded. Assuming a labor wage of ¢2.00 per man-hour, the cost of budding will be as follows:

a) Preparation of budwood ..... 1 hour
b) Actual budding ..... 1 hour
c) Unwrapping, rubbing of undesired growth, tying up ..... 1 hour
d) Bending of stock plants ..... 1 hour
e) Shaping ..... 1 hour

The cost per 30 buddings would thus be 5 x ¢2.00, or ¢10.00, and the cost per budding, ¢0.33. Allowing ¢0.07 for wrapping material, the cost of a 8-months' old budding, averaging 4 feet in height, and having a stem diameter of one inch, would be around ¢0.40. The cost in establishing a two-limb budding would require extra time, but the final cost would be about the same.

The relative cost in this experiment was ¢1.15 for the buddings against ¢2.00 for the rooted cuttings. Despite poor timing, the budding results in this experiment were very promising and, since budding can be done in task work or contracted, the cost of budding may be reduced still more. The basis for a successful union, using the patch method, is the following:

a) To have healthy growing stock plants right from the beginning;

b) To bud stock plants with a stem diameter between 2.5 and 4.0 cm.

c) To use proper budwood, preferably obtained from a budwood garden.

In addition to the points mentioned above, speed and care are required to allow a high percentage of successful unions. It was observed that, of older stock plants, the bark easily separated from the wood and thus made the budding operation simple and cheap. The budding operation was made by the author but a more experienced budder may attain a higher efficiency.

Final Assessment

In this experiment, the various operations were speeded up in order to obtain an early establishment of the plants. Owing to the plant design and the use of entirely two different types of plants, i.e. rooted fan cuttings with a superficial branched root system, and seedling stock with a deeper tap root system, it was not feasible to keep separate cost records. For a proper cost assessment in the future, using different types of planting material, it is suggested that the experiment comprise larger blocks. In this way, the investment, the growth performance and the survival rate could more easily be determined.

In order to attain a high survival rate and to induce a vigorous growth, utmost care was required in the first year after planting the rooted fan cuttings. Consequently the investment for rooted cuttings per unit of area was rather high. In 19 months

after planting the cuttings, the maintenance share was ¢8.37 per plant, representing 49 percent of the total investment in this experiment. It is not likely that with less maintenance, and a lower investment, the same results might be achieved.

In Table 26, the breakdown of the investment per operation, as well as the number of cycles, is given. It is obvious that weeding in the rows comprised almost 52 percent of the maintenance cost. Since symmetrical growth of the cuttings was preferred, the adjustment of shade required another large expense, which in turn increased weeding expenses. In the case of seedlings which can be produced in a nursery at a fraction of the cost of a rooted cutting, the investment per seedling stock until budding time can be kept relative low. The main requisite for budding at stake is to have healthy and vigorous growing stock plants. The growth results of buddings in this experiment showed that, with the approach of "late budding", best results were obtained.

Considering the high labor fees in the Atlantic zone in Costa Rica, namely, almost US$2.00 per man-day, and the expensive nature of the maintenance practices necessary for rooted fan cuttings, the planting of seedlings grown from hardy and uniform material would probably reduce the investment for the first two years of operation. It is too early to state which type of vegetative propagation is to be preferred. Fan buddings and fan cuttings presented difficulty in obtaining properly shaped plants, while the shaping of chupon buddings was simple; the resulting plants resemble the future seedling-type trees.

In this experiment, 24 months were allowed for the replanting process. It is possible that, by extending the period of re-establishment at least 12 months, the process of replanting old field may be performed more efficiently and also more economically. Unfortunately, these facts were not fully appreciated because of the limited time available.

The replanting of old cacao fields under the same conditions as those of this experiment, might preferably be carried out in three steps:

1.	Clearing and re-shading	- Time :	12 months
2.	First growth period	-	15 "
3.	Second growth period	-	9 "
	Total		36 "

The investment for these 36 months should not exceed ¢6,000.00 or about US$900.00 per hectare. Assuming 600 cacao plants per Ha., the investment per plant would thus be ¢10.00 or US$1.50. Assuming a market price of US$0.30 per pound of dry cacao, the investment per hectare would be equivalent to the value of 3000 pounds of dry cacao.

VI CONCLUSIONS

Pre-planting Practices

1. The clearing of old cacao trees, using mechanical means, was a good and efficient practice. However, cost and labor time could have been reduced considerably by cutting up the trees *in situ* and spreading out the trash in rows.

2. It proved to be good practice to remove the old shade trees at clearing time and to plant new shade immediately afterwards.

3. Clearing practices should commence in the dry season and should be terminated before the onset of the following wet season.

4. Planting of the young cacao should not be carried out at the end of the wet season, but at the beginning of a new wet period.

5. Omitting the expensive way of clearing the old cacao and re-shading, the initial cost of replanting may be reduced by at least 40 percent.

6. In this experiment, the process of replanting took only 5 months to be completed. Considering the economic aspects, this process should rather be stretched out to at least 9 months.

First Results

1. Despite early planting, the high survival of the young cacao fan cuttings (3 months old) is noteworthy. This high survival was primarily due to a careful but costly maintenance, and secondly, to the hedge shade.

First Results (cont'd)

2. The Crotalaria shade gave excellent protection during the drier period which followed the planting of the young cacao. In the wetter period, air humidity could be satisfactorily regulated by periodic prunings of the temporary shade.

3. Hoeing and tillage practices are economically justified in young cacao plantings and may replace the system of ring weeding or arrondeering. Cutlass wounds on young cacao plants may be avoided when hoeing is practised.

4. The planting of banana shade (not an export type), as a source of income, was economically not justified. Where soil conditions are favourable, the planting of an export type of bananas may be justified.

5. The Erythrina shade which was planted from large stakes required 9 to 12 months to become established. In about 7 months time a proper banana shade was obtained. The cost in establishing a Erythrina shade was considerable less than the cost of establishing a banana shade.

6. The periodical adjustment of the temporary shade was a good practice in order to speed up the radial growth of the seedling root stocks and to induce a symmetrical growth of the rooted cuttings.

Final Results

1. The plant design in this experiment did not permit the keeping of separate cost records in order to evaluate the investment for the three types of vegetatively propagated cacao at maturity.

Final Results (cont'd)

2. The maintenance of rooted cuttings until they became established required close attention and skill in order to secure a high survival and proper growth.

3. Since part of the seedling stock plants showed a restricted growth, probably due to poor physical soil conditions at scattered soil sites, it is of importance to prepare the soil sites properly prior to planting the young cacao.

4. In sites where banana shade was replaced by Erythrina shade, a vigorous growth of the young cacao was observed. It is possible that, owing to its vigorous root system, this shade may have improved the physical status of the soil.

5. In order to acquire proper results with the method of budding at stake, two essential points, apart of its technique, should be considered:

    a) To have stock plants with a stem diameter between one and two inches, and
    b) To have vigorously growing stock plants right from the beginning.

6. It was a good practice to retain the upper part of the budded stock plants until 4 months after bending them back. Despite the rapid scion growth, an increase in radial growth of the stock plants was thus obtained.

7. It is too early for definite conclusion, but chupon buddings, resembling the true seedling type trees, would probably be preferred, owing to their fast and uniform growth. In addition, their after-care is simple and cheap.

Final Results (cont'd)

8. Although selected material for stock plants was not available, yet non-hybrid purple-coloured seed of Amelonado-type cacao proved to be successful as rootstock.

9. Assuming similar conditions as in this experiment, old cacao fields in Costa Rica may be successfully re-planted with rooted fan cuttings. The actual future yields and returns should disclose whether rooted fan cuttings (nursery method) or buddings at stake (field method) would be preperable. Both methods seem to have high efficiency, but the field method is apparently a more simple and a more economical procedure.

VII SUMMARY

An experimental area of 1.15 hectares was completely cleared of former growths and immediately replanted with shade trees. Planting of the young cacao, consisting of 192 rooted fan cuttings and 384 seedling rootstocks, was completed in 5 months after the former growths were cleared. In this experiment, the young cacao was spaced 3 x 5 metres and 4 x 4 metres.

The initial cost of re-planting amounted to ¢5.042.96 and the operations required 190.6 man-days and 165 tractor hours.

The survival, after nine months of growth in the field, was 87 percent for the rooted fan cuttings and 84 percent for the seedling rootstocks before budding. The seedlings then averaged a vertical height of 102.1 cm. with a stem diameter of 1.80 cm., whereas the average height of the rooted fan cuttings at the end of the same period was 64.7 cm.

The banana type of shade (not the export type of banana) was economically a failure and was gradually replaced by a tree legume shade, namely, Erythrina poeppigiana. The hedge shade of Crotalaria anagyroides was expensive to establish but it provided optimum growing conditions for the young cacao.

The expenditure in nine months after the cacao was planted amounted to ¢2,436.96, and this period required 132.9 man-days.

In twelve months of growth 80 percent of the cacao rootstocks attained a stem diameter of 2.50 cm. or one inch. The efficiency of budding at stake three months after the buddings were made, was about 70 percent. The efficiency of the production of rooted fan cuttings at planting time was 50 percent.

In six months of growth, the chupon buddings attained an average height of 112 cm. against 110 cm. for the fan buddings; the limb diameter over the same period was 2.37 cm. for the

chupon buddings and 1.96 cm. for the fan buddings. The stem diameter of the stock plants averaged 3.75 cm., representing a growth increase of 1.25 cm. from the time when the stocks were budded. After 18 months of growth, the rooted fan cuttings averaged 132 cm. in height and 4.12 cm. for the limb diameter.

The expenditure for the last 10 months was ¢2,395.63, and 158.2 man-days were required.

The percentage of vigorously growing plants is given below. These plants had a vertical height of 130 cm. or more, and showed a distinct symmetrical or upright growth. The percentage for the rooted cuttings was 71.3 percent and for the chupon and fan budgins, 65.2 and 63.2, respectively.

The total expenditure over a period of 24 months amounted to ¢9.875.53, and 483.2 man-days were required for this area comprising 1.15 hectares. Arranging the treatments in larger and solid blocks, the cost assessment of each treatment may be analyzed per unit and per plant.

VII RESUMEN

Se procedió a la limpia completa del área experimental que comprendió de 1.15 hectáreas e inmediatamente se plantaron los árboles de sombra provisional. Se sembraron 192 estacas enraizadas provenientes de ramas y 384 patrones de origen semilla. Este trabajo se terminó a los cinco meses de haberse limpiado el terreno. Este experimento se sembró a distancias de 3 x 5 metros y 4 x 4 metros.

El costo inicial del replante ascendió a ¢5.042.96 y las operaciones requirieron 190.6 jornales y 165 horas-tractor.

Después de 9 meses de crecimiento en el campo se obtuvo un 87 por ciento de prendimiento en las estacas enraizadas de origen rama y un 84 por ciento en las plántulas de semilla. El promedio de altura vertical de las plántulas fue de 102.1 cm. siendo 1.80 cm. el diámetro del tallo. En este mismo período la altura promedio de las estacas enraizadas provenientes de ramas fue de 64.7 cm.

La sombra de banano (tipo no exportación) fue un fracaso económico por lo cual fue substituída por la leguminosa (Erythrina poeppigiana). El seto de Crotalaria anagyroides para dar sombra a las plantas jóvenes de cacao fue algo caro, pero dió óptimos resultados.

El gasto durante los nueve meses de plantado el cacao ascendió a ¢2.436.96 y durante este período se necesitaron 140.6 jornales.

Después de 12 meses de crecimiento en el campo los patrones de cacao alcanzaron un tallo de 2.50 cm. de diámetro o una pulgada. Se obtuvo un 70 por ciento de eficiencia en los injertos de estacas después de 3 meses de hechos éstos. También se obtuvo un 50 por ciento de eficiencia en la producción de estacas enraizadas al tiempo de siembra.

En seis meses de crecimiento los injertos de chupon alcanzaron un promedio de altura de 112 cm. en comparación con los injertos de rama que obtuvieron 110 cm.; el diámetro de la rama en este mismo período fue de 2.37 cm. en los injertos de chupon y de 1.96 cm. en los de rama. El promedio del diámetro de los tallos fue de 3.75 cm. representando un aumento en crecimiento de 1.25 cm. Después de 18 meses de crecimiento en el campo se obtuvo un promedio de 132 cm. de altura para estacas enraizadas de ramas y el diámetro de las ramas fue de 4.12 cm. Esto último representa la suma de dos recuentos por planta.

El desembolso para los 10 meses fue de ₡2.395.63 y requirió 158.2 jornales.

A continuación se dal el porcentaje de plantas vigorosas, es decir de aquellas que miden 130 cm. o más de altura, y que presentan un crecimiento simétrico. Se obtuvo un porcentaje de 71.3 en estacas enraizadas; y el porcentaje para injertos de chupones y de ramas fue de 65.2 y 63.2 respectivamente.

Los gastos totales para el período de 24 meses ascendieron a la suma de ₡9.875.53 y se requirieron 483.2 jornales en el área de 1.15 hectáreas. Haciendo arreglos de los tratamientos en bloques más grandes el costo para cada tratamiento podría analizarse por unidad y por planta.

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X APPENDIX

TABLE 16

Monthly rainfall in inches, period 1949-1956
Finca "La Lola", Costa Rica

Month	Inches			Days		
	Mean	Max.	Min.	Mean	Max.	Min.
January	12.26	21.98	6.59	19.6	25	16
February	8.94	21.43	3.16	17.0	23	9
March	6.49	9.02	3.92	17.1	22	11
April	7.00	10.28	3.94	16.0	21	9
May	13.68	26.08	6.55	17.3	27	13
June	13.15	22.74	5.61	18.3	23	12
July	14.16	22.73	8.01	22.0	27	17
August	8.21	20.36	1.69	17.0	24	6
September	5.15	10.47	1.61	12.7	17	10
October	11.71	22.68	6.01	19.2	24	15
November	18.34	34.52	9.79	22.2	26	14
December	20.76	31.79	8.68	23.0	27	14
Total	139.85	-	-	221.4		

TABLE 17

Annual rainfall in inches, period 1949-1956
Finca "La Lola", Costa Rica

Year	Rainfall			Wettest Month		Driest Month	
	Total in.	Deviation inches	Total days	Month	Inches	Month	Inches
1949	158.46	+ 18.61	234	Nov.	34.52	Feb.	3.38
1950	173.12	+ 33.27	237	Dec.	30.91	Sept.	1.61
1951	132.20	- 7.65	194	Feb.	21.43	May	6.55
1952	120.79	- 19.06	206	Dec.	17.56	Sept.	2.22
1953	131.61	- 8.24	247	Aug.	20.36	Sept.	1.86
1954	141.91	+ 2.06	231	Dec.	31.79	Feb.	3.16
1955	105.40	- 34.45	200	Oct.	17.36	Aug.	1.69
1956	155.33	+ 15.48	242	July	22.73	Feb.	3.37
Av.	139.85		224				

TABLE 18

Some additional weather data; period 1952-1956
Finca "La Lola", Costa Rica

Months	Rainfall (inches)			Solar radiation hr.			Rainless days 6:00AM-6:00PM.		
	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
January	14.86	21.98	6.59	123	171	64	16	18	13
February	5.40	8.31	3.16	132	144	122	19	22	15
March	6.29	8.37	3.92	152	163	139	22	24	19
April	7.36	10.28	3.94	148	218	113	21	25	16
May	12.15	18.72	7.61	125	147	92	16	20	12
June	9.20	13.20	5.61	114	121	107	19	23	12
July	13.59	22.73	8.01	114	129	100	16	23	11
August	8.25	20.36	1.69	134	186	101	18	29	13
September	5.21	10.47	1.86	163	189	160	21	24	17
October	12.88	22.68	6.01	126	152	100	16	20	11
November	15.77	23.74	10.53	106	147	90	13	18	9
December	20.65	31.79	12.48	105	121	91	12	16	8
Total	131.01	-	-	1542	-	-	209	-	-

TABLE 19

Some weather data at annual levels; period 1952-1956
Finca "La Lola", Costa Rica

Year	Rainfall inches	Solar radiation hours	Number days 6:00 AM - 6:00 PM. Rainy	Rainless	Rainy days 24 hours period
1952	120.79	1667	147	219	206
1953	131.61	1530	183	182	247
1954	141.91	1476	166	199	231
1955	105.40	1579	127	238	200
1956	155.33	1456	160	206	242
Total	655.04	7708	783	1044	1126
Average	131.01	1542	157	209	225

TABLE 20

Comparative weather data. 1955-1957
Finca "La Lola", Costa Rica

Month	Rainfall		Solar radiation hrs.		*
	Inches	MM	Total	± 6 hour/day	
1955					
September	4.00	100	160	108	1.60
October	17.36	434	129	74	0.30
November	14.89	377	90	35	0.24
December	12.44	311	100	37	0.32
1956					
January	21.98	549	64	21	0.11
February	3.37	84	129	62	1.53
March	8.02	200	153	104	0.76
April	9.43	236	154	88	0.65
May	18.72	468	92	35	0.20
June	7.73	193	111	25	0.57
July	22.73	568	100	52	0.18
August	5.69	142	135	68	0.95
Total	147.36	3662	1417	709	0.38 **
September	10.47	262	161	116	0.61
October	6.01	150	152	95	1.01
November	14.77	369	92	37	0.25
December	26.41	660	113	52	0.17
1957					
January	9.32	233	153	112	0.66
February	6.01	150	128	69	0.85
March	2.20	55	165	112	3.00
April	4.21	105	151	92	1.43
May	16.03	401	144	80	0.35
June	11.31	283	115	41	0.41
July	26.04	661	76	22	0.11
August	19.18	479	94	16	0.18
Total	151.96	3808	1544	844	0.41 **

* Ratio of rainfall in MM and solar radiation in hours.
** Mean

TABLE 21

Replanting of old cacao field. Order of operations

Year	Months	Order	Operations
1st.	Aug. - Sept.	1	Clearing old cacao trees
"	Sept. - Oct.	2	Felling and clearing old shade trees
"	Sept.	3	Discing and lining up
"	Sept. - Dec.	4	Production of cacao plant material
"	Oct. - Dec.	5	Planting temporary shade
"	Dec. - Jan.	6	Planting young cacao
2nd.	Feb. onwards	7	Maintenance young cacao ★
"	May	8	Supplying shade and adjusting temporary shade
"	Aug.	9	Drainage
"	Oct.	10	Adjusting temporary shade, planting permanent shade
3rd.	Jan. - Feb.	11	Tillage and mulching cacao
"		12	Budding seedling cacao
"	May	13	Shaping rooted cacao cuttings
"	May - July	14	Adjusting shade
"	July	15	Shaping buddings
"	Aug.	16	Hoeing, tillage and earthing up young cacao

★ Maintenance includes hoeing, tillage, row weeding, inter-row weeding, applying fertilizers, disease and insect control.

TABLE 22

Monthly breakdown of costs (Phase 1)

Month	Labor hours	Labor earnings	Tractor hours	Tractor fees ¢	Value material ¢	Total cost ¢
1955						
August	238	433.75	83	547.80	-	981.55
September	394	970.10	72	475.20	-	1.445.30
October	279	512.60	13	85.80	244.00	342.40
November	239	408.55	3	19.80	-	428.35
December	237	460.70	10	66.00	44.00	570.70
1956						
January	347	609.10	6	39.60	50.00	698.70
Sub-total 1.30 Ha.	1734	3.394.80	187	1.234.20	338.00	4.967.00
Sub-total 1.15 Ha.	1525	2.987.42	165	1.086.09	297.45	4.370.96
Cacao Plant Material	-	-	-	-	672.00	672.00
Total	1525	2.987.42	165	1.086.09	969.45	5.042.96

TABLE 22a

The breakdown of cost per operation (Phase 1)

Items	Labor hrs.	Tractor hours	Labor earnings	Tractor fees ¢	Value material ¢	Total cost ¢	%
Land preparation	650	151	1.397.97	993.17	21.12	2.412.26	47.8
Re-shading	492	-	870.93	-	211.20	1.082.13	21.5
Planting	383	14	718.52	92.92	737.13	1.548.57	30.7
Total	1525	165	2.987.42	1.086.09	969.45	5.042.96	
Percentage			59.3	21.5	19.2		

TABLE 22b

The breakdown of land preparation cost

Items	Labor hrs.	Tractor hrs.	Labor earnings ¢	Tractor fees ¢	Value material ¢	Total cost ¢
Cutting up old cacao trees	155	-	514.80		-	514.80
Mechanical clearing	203	101	361.81	667.92	-	1.039.73
Felling shade trees	121	-	223.43	-	-	223.43
Removal of trees and stones	49	28	86.24	185.86	-	272.10
Discing and levelling	73	21	127.91	139.39	-	267.30
Lining	49	-	83.78	-	21.12	104.90
Total	650	150	1.397.97	993.17	21.12	2.412.26

TABLE 22c

The breakdown of re-shading cost

Items	Labor hours	Labor earnings ¢	Value material ¢	Total cost ¢
Musa shade	205	381.74	105.60	487.34
Crotalaria shade	231	393.45	88.00	481.45
Erythrina shade	56	95.74	17.60	113.34
Total	492	870.93	211.20	1.082.13

TABLE 22d

The breakdown of planting cost

Items	Labor hrs.	Tractor hrs.	Labor earnings ¢	Tractor fees ¢	Value material ¢	Total cost ¢
Pre-planting weeding	111	-	219.65	-	-	219.65
Holing	21	-	66.53	-	-	66.53
Planting	143	14	248.34	92.92	65.13	406.39
Planting-plant material	-	-	-	-	672.00	672.00
Maintenance	108	-	184.00	-	-	184.00
Total	383	14	718.52	92.92	737.13	1.548.57

TABLE 23

Monthly breakdown of cost (Phase 2)

Months	Labor hrs.	Labor earnings ¢	Tractor fees ¢	Value material ¢	Total cost ¢
1956					
February	189	321.30	40.00	35.25	396.55
March	107	181.90	-	1.00	182.90
April	176	299.20	48.00	66.00	413.20
May	120	204.00	-	1.00	205.00
June	76	132.78	48.00	44.00	224.78
July	127	222.70	-	28.80	251.50
August	105	290.16	-	14.50	304.66
September	64	207.75	-	1.00	208.75
October	99	225.60	-	24.00	249.60
Total	1063	2.085.39	136.00	215.55	2.436.94

TABLE 23a

The breakdown of cost per operation (Phase 2)

Items	Labor hrs.	Labor earnings ¢	Tractor fees ♣ ¢	Value material ¢	Total cost ¢	No. cycles
Interrow weeding	161	322.10	136.00	-	458.1o	5
Hoeing & tillage	236	432.84	-	-	432.84	5
Row weeding	433	766.50	-	-	766.50	4
Spraying	58	98.60	-	8.00	106.60	7
Fertilizer	24	40.80	-	63.00	103.80	3
Supplying cacao	19	32.30	-	97.75	130.05	3
Drain share	-	161.05	-	-	161.05	-
Shade and shade regulation	132	231.20	-	46.80	278.00	-
Total	1063	2.085.39	136.00	215.55	2.436.94	
Percentage		85.0	6.0	9.0		

♣ These fees are for the use of the Gravely "mechanical scythe".

TABLE 24

Monthly breakdown of cost (Phase 3)

Month	Labor hours	Labor earnings ¢	Tractor fees ¢	Value material ¢	Total cost ¢
1956					
November	116	197.20	-	21.00	218.20
December	37	80.50	-	1.00	81.50
1957					
January	242	414.80	-	1.00	415.80
February	109	185.30	-	1.00	186.30
March	-	-	-	-	-
April	144	291.20	-	-	291.20
Total	648	1.169.00	-	24.00	1.193.00

TABLE 24a

The breakdown of cost per operation

Items	Labor hours	Labor earnings ¢	Value material ¢	Total cost ¢	No. cycles
Interrow weeding	64	144.00	-	144.00	2
Row weeding	192	384.00	-	384.00	2
Hoeing & tillage	250	399.60	-	399.60	2
Spraying	20	34.00	4.00	38.00	4
Shade	66	112.20	20.00	132.20	-
Budding (partial)	56	95.20	-	95.20	-
Total	648	1.169.00	24.00	1.193.00	
Percentage		98.0	2.0	-	

TABLE 25

Monthly breakdown of cost (Phase 4)

Months	La-bor hrs.	Labor earn-ings ¢	Trac-tor fees ¢	Value mate-rial ¢	Total cost ¢
1957					
May	54	91.80	19.80	11.15	122.75
June	192	344.00	-	28.98	372.98
July	122	207.85	13.20	15.30	236.35
August	250	443.05	13.20	14.30	470.55
Total	618	1.086.70	46.20	69.73	1.202.63

TABLE 25a

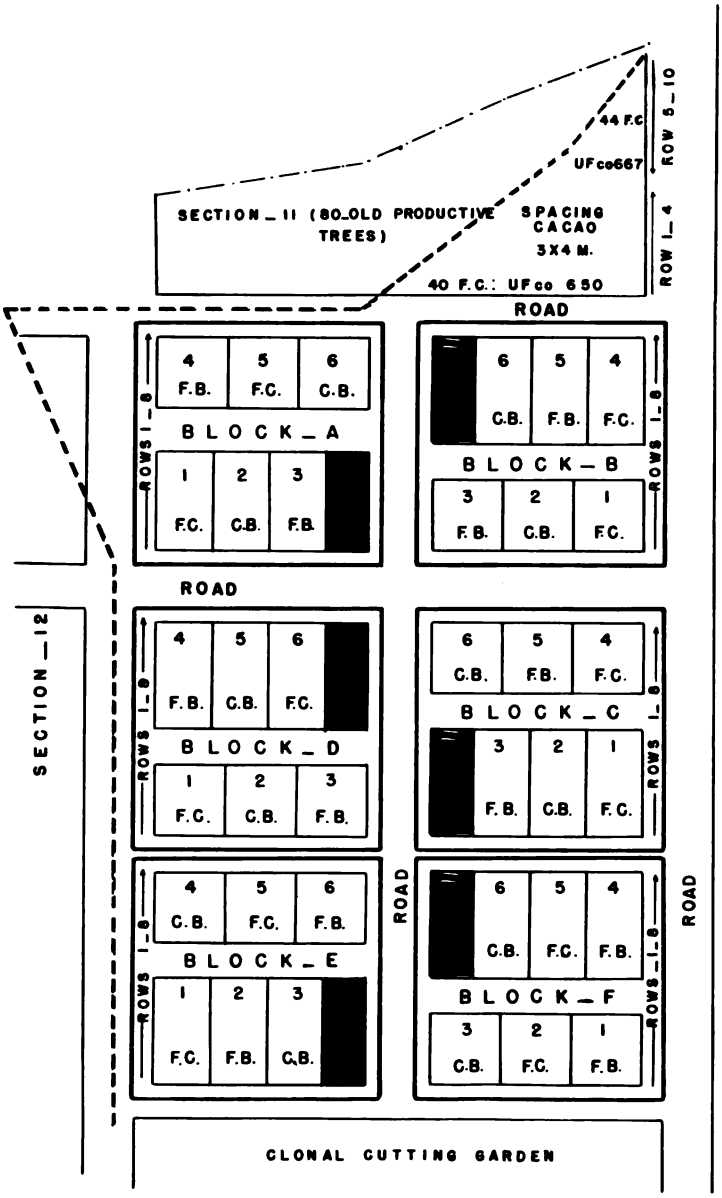
The breakdown of cost per operation

Items	La-bor hrs.	Labor earn-ings ¢	Trac-tor fees ¢	Value mate-rial ¢	Total cost ¢	No. cycles
Interrow weeding	64	144.00	-	-	144.00	2
Row weeding	152	258.40	-	-	258.40	2
Hoeing & tillage	152	258.40	-	-	258.40	2
Spraying	34	58.70	46.20	40.75	145.65	3
Shade	136	231.20	-	-	231.20	3
Supplying cacao	40	68.00	-	-	68.00	2
Misc. costs	40	68.00	-	28.98	96.98	-
Total	618	1.086.70	46.20	69.73	1.202.63	
Percentage		90.3	3.9	5.8	-	

TABLE 26

A compilation of the operations for the period ending August 31, 1957

Items	Man-hours	Man-days	No. cycles	Total cost ¢	Per-centage
Interrow weeding	333	41.6	9	800.50	16.5
Row weeding	777	97.1	10	1.408.90	29.1
Hoeing & tillage including mulching and earthing up	638	79.8	9	1.090.84	22.5
Spraying	112	14.0	16	290.25	6.0
Fertilizer	32	4.0	4	146.38	3.3
Shade and shade adjustment	334	41.7	9	641.40	13.3
Supplying	59	7.4	5	198.05	4.1
Drain share	-	-	1	161.05	3.3
Budding (partial)	56	7.0		95.20	1.9
Total maintenance (19 months)	2341	292.6		4.832.57	-
Land preparation	650	81.2		2.412.26	24.4
Re-shading	492	61.5		1.082.13	11.0
Planting (cacao)	383	47.9		1.548.57	15.6
Maintenance (19 months)	2341	292.6		4.832.57	49.0
Total	3866	483.2		9.875.53	-



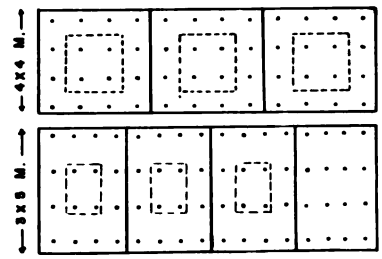


FIG. 1 LAYOUT OF EXPERIMENT SHOWING ON THE LEFT THE NUMBERING OF BLOCKS, PLOTS AND TREATMENTS AND ABOVE THE DISTRI_ BUTION OF CACAO PLANTS PER BLOCK OF TWO SPACINGS.

LEGEND: F.C. = ROOTED FAN CUTTING
F.B. = FAN BUDDING
C.B. = CHUPON BUDDING
■ = NON EXPERIMENTAL PLOT
— — TRAMWAY

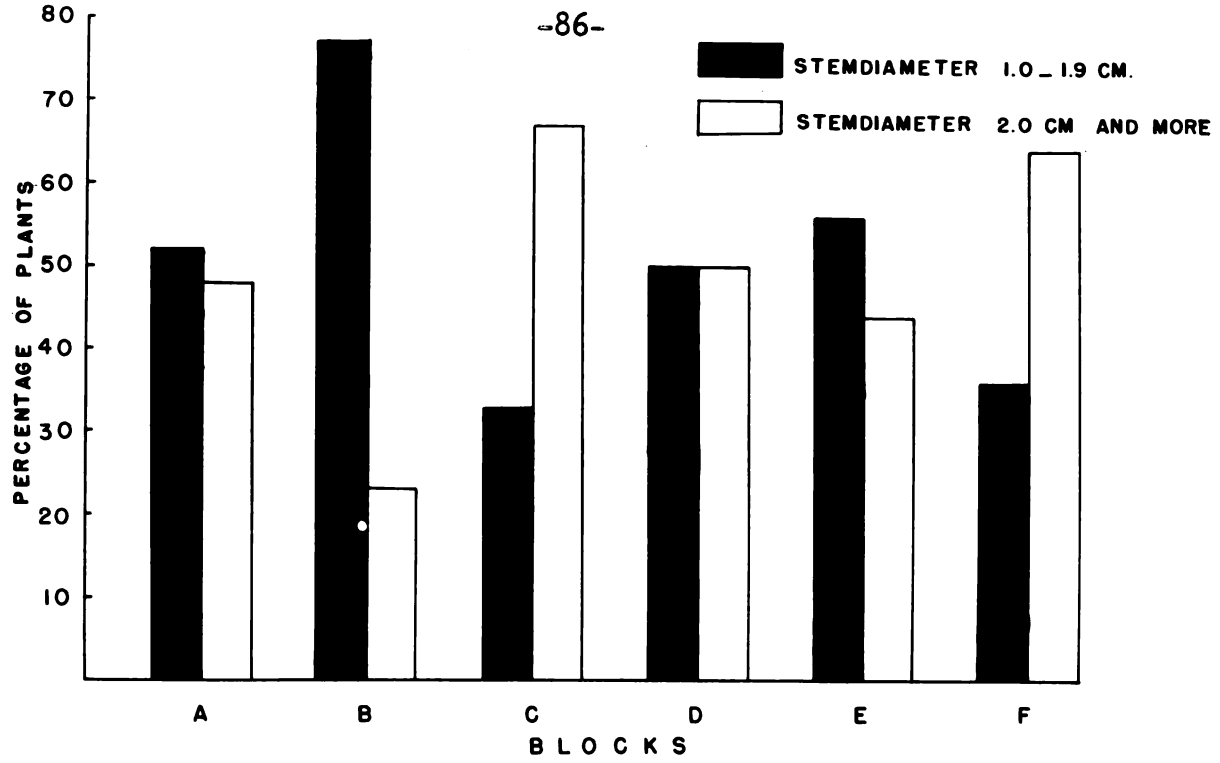


FIG. 2 STEMDIAMETER VARIABILITY IN CM OF SEEDLINGSTOCKS IN THE SIX BLOCKS, GROWN OVER A PERIOD OF NINE MONTHS

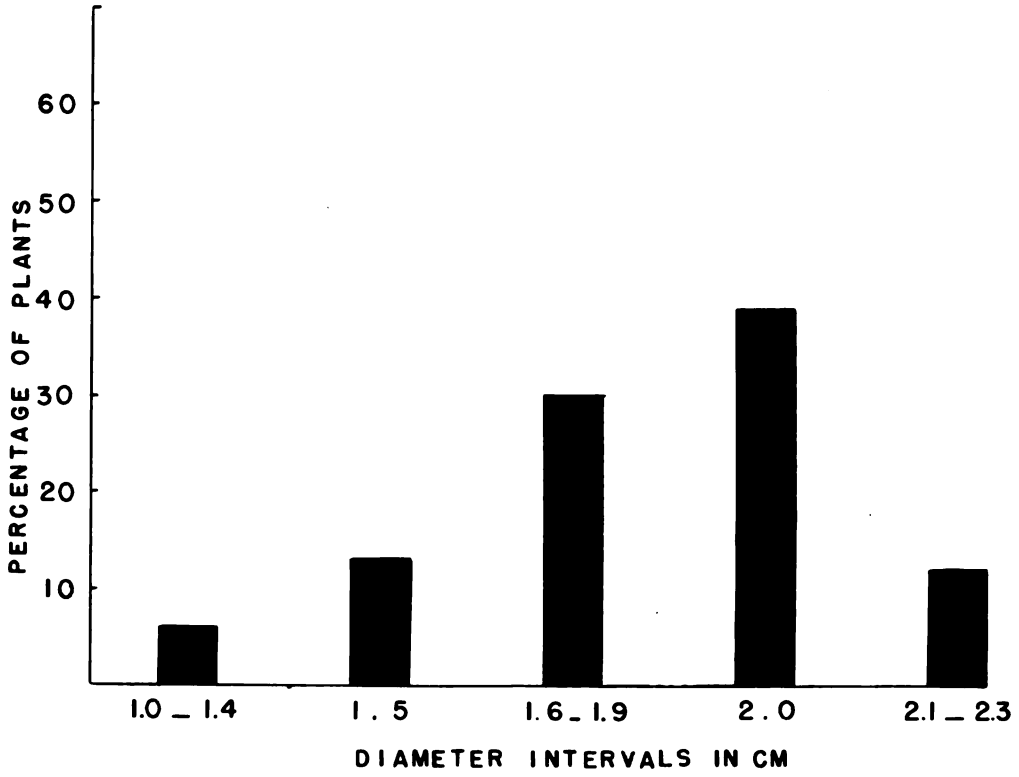


FIG. 3 THE DISTRIBUTION OF STEMDIAMETER IN CM OF SEEDLINGSTOCKS, GROWN OVER A PERIOD OF NINE MONTHS

Fig. 4 15 months-old Amelonado stock plants patch budded at stake at 20 cm. from ground level.

Fig. 5 The same stock plant as in Fig. 4, but with the wrappings removed, 3 weeks after inserting the bud. Note the bud patch is smaller than the opening in the stock plant.

Fig. 6 The preparation of budwood on suckers arising at ground level from bearing 5-year-old rooted fan cuttings.

Fig. 7 Two-limb fan budding showing symmetrical growth. Note the limbs are unbranched for about 80 cm. Budding was done at stake on one inch thick stock plants. Fan budding is about 6 months old.

Fig. 8 Two-limb fan budding of the same age as in Fig. 7. Note two limbs arising from the same bud patch.

Fig. 9 Two-limb fan budding six months old, but showing less desirable growth. Reasons for such a whippy growth cannot be given.

Fig. 10 Six-month old chupon budding which was made at stake but showing less desirable low forking (about 60 cm from ground level).

Fig. 11 Six-month old chupon budding which was made at stake showing desirable forking (about 1.00 metre from ground level). Note that the slit and bent upper part of stock plant is still attached.

Fig. 12 Well-pruned six months old chupon budding which was made at stake on 15-month old Amelonado stock. Budding averaged a height of 1.30 metre and limb diameter of one inch.

Fig. 13 A well-developed 18 months-old rooted fan cutting. Note base branching two-limb structure showing symmetrical growth.

Fig. 14 18 months-old rooted fan cutting, not pruned and showing a whippy growth.

Fig. 15 Same plant as in Fig. 14, but pruned. Note the white cuts where the former limbs were pruned.