THE VEGETATIVE PROPAGATION OF CACAO.*

By E. E. Cheesman, Imperial College of Tropical Agriculture, Trinidad, British West Indies.

It is noteworthy that all the investigators contributing to the perfection of the budding technique in different countries were inspired by the advantages to be derived from the cultivation of uniform types of cacao, in place of the heterogeneous seedling populations which are still the rule. Some mentioned earlier bearing as an additional point in favour of budded trees, but all stressed uniformity, and especially uniformity of high yielding power, as the great desideratum.

In quest of uniformity all attempted, quite rightly, to adapt to cacao, horticultural methods long established for temperate orchard crops; but in quite recent years temperate orchard practice in this respect has again moved ahead. Researches, in which the East Malling Station has taken a leading part, have shown that uniformity of yield and of other characters in temperate fruit trees depends on uniformity of rootstock as well as uniformity of scion. There is no reason *a priori* to suppose that these findings will not apply to cacao, but rather the reverse.

For this reason, when in 1930 a Cacao Research Scheme was launched at the Imperial College of Tropical Agriculture, it was felt necessary to approach the problems of vegetative propagation from a new angle. There were many problems relating to budding still awaiting solution, but it was decided to concentrate attention, so far as the propagation side of the programme was concerned, on efforts to raise cacao trees vegetatively *on their own roots.*

The numerous problems of stock-scion interactions could the more profitably be deferred for later attack because in the absence of clonal rootstocks the most promising instrument for their solution was not yet available. A summary of the results achieved and of the present outlook is the object of this paper, but, in order to explain the terminology which must be employed, a brief description of the mode of branching of the cacao tree must be given first.

Branching of the Cacao Tree.

A young cacao seedling growing healthily produces a single vertical unbranched stem, on which the leaves are arranged in a $\frac{3}{8}$ spiral, and which later forms the main trunk of the tree. After a variable time, and presumably when it has attained a certain physiological condition not yet defined, the terminal bud divides into three, four, or five, which grow out into oblique or almost horizontal branches (Fig. 1). The whorl of branches so formed is known as the fan or by the Trinidad term jorquette (pronounced horkette), the latter name being preferable, because the word fan or fan-branch can then be used for the individual limbs of the jorquette without danger of confusion. The fan branches have their leaves in two ranks, and bear secondary branches of higher orders, all with leaves in two ranks.

* Extracted from *Journal of the Imperial College of Tropical Agriculture*—Trinidad.

At a later stage a vertical branch arises from the main trunk just below the jorquette. Since it arises on old wood, there is difficulty in determining its exact origin, but it is probably axillary. This branch is known as a chupon; it has its leaves in a spiral, and it repeats exactly the behaviour of the seedling axis, growing up through the jorquette and in due course branching into a second jorquette some feet higher. A third and fourth tier may be added to the tree in the same way. The arrangement is often obscured in old trees by loss of the lower branches by reduction of the vertical part of one "storey" so that two jorquettes arise from almost the same point, or in other ways, but it can usually be traced on careful examination.

As the tree grows older, it nearly always produces from the base of the trunk, at or near ground level, additional chupons (also referred to as "suckers", "water-shoots", or "gormandizers") and if left untended may develop into a clump. In cultivation these basal chupons are most commonly cut out, though some planters like to leave two or three. If the original tree is showing signs of disease or senility, it is usual to allow a strong chupon to grow, and when it is in a condition to replace the old trunk to cut out the latter instead. For this reason "age" in cacao fields is a complex subject, since an old tree, said to be of a certain age, may have been renewed (so far as the parts above ground are concerned, and probably in roots as well) several times since the actual planting.

Normally chupons do not branch, except when they make their jorquettes but they may be induced to do so by bending them over or cutting them back, and when the axillary buds are thus stimulated into growth they give rise in every case to branches of the same type, i.e., to chupons. Fan branches on the other hand branch freely, and their axillary buds likewise normally produce shoots like themselves, i.e., fan branches of the second or higher orders. If, however, fan branches are cut hard back they will sometimes produce chupons behind the cut. Moreover, it is by no means uncommon in the field to find chupons arising from fans, and although the physiological equivalent of pruning, in the shape of a wound or canker, can often be found as the cause, such is not invariably the case.

The so-called "dimorphism" of cacao branches is thus clearly marked, yet by no means absolute and there seems to be a certain plasticity of behaviour in both kinds of buds. Buds on fan branches (fan buds) especially seem able to give rise to either fans or chupons, according to their physiological state, and shoots may be found on fan branches having a spiral phyllotaxis below and a two-ranked arrangement above. Axillary buds on chupons are less plastic, but physiological factors must certainly determine the height at which the terminal chupon bud produces its jorquette, since that height varies without any apparent morphological or genetic reason.

The practical importance of the dimorphism in propagation lies in the fact that the entire habit of the vegetative progeny depends on the type of branch or bud used. Thus in the early grafting experiments, fan branches were inarched on seedlings held in bamboo pots near the tree, and Jones describes his grafted plants as branching a few inches above the point of union and forming bushy specimens. In the budding method described as used in Jamaica and Haiti, trees were pruned to provide vigorous chupons for budwood and the result was that the budded progeny developed a main trunk. The same applies to Stahel's technique, in which chupon buds are recommended as preferable. In Trinidad,

however, fan buds have usually been employed, and as a result budded plants can be recognized at a glance by their lack of trunk, and by their spreading two-ranked branches, which need some training to make a symmetrical tree. It is to be noted that whereas there is always an abundance of fan material available on a healthy tree, there is very often under plantation conditions, little or no chupon material to be had without recourse to manipulation. Exactly the same considerations apply in propagation of scions on their own roots.

Propagation by Cuttings.

The rooting of cacao cuttings has possibly been achieved, though unrecorded, many times in different countries, but it has never previously attracted attention as an important contribution to the technique of crop improvement. Since the end of 1930, however, a systematic survey of the possibilities of the method has been made by E. E. Pyke, working in these laboratories, and the conclusions here given are based entirely on his researches. Detailed accounts have appeared elsewhere and only a summary will be attempted.

The work began with a general survey of all possible means of vegetative propagation, excluding budding and grafting. This included trials with hardwood and softwood stem-cuttings and root-cuttings, and soon demonstrated beyond doubt that between those the greatest hope of success lay in the use of softwood. By "softwood" is meant shoots that are mature but which still retain their leaves, and which are set to generate a root-system without removal or loss of those leaves; in actual texture such shoots are semi-hardwood. The success with this kind of cutting was of such an order that there appeared to be no possible economic advantage in pursuing investigations with hardwood, and subsequent work was devoted to standardization of method.

The second year's work established several principles. In the first place it showed an important connexion between the physiological condition of a tree and the behaviour of cuttings taken from it. Old trees and trees grown without shade are alike unsuitable for supplying cuttings. The general appearance of shoots likely to root well is now known, but much physiological research remains to be done before the constitutional features of such material can be defined. In the second place comparisons were made between chupon cuttings and fan cuttings, which showed little difference in ability to root, but marked differences in the type of rooting and subsequent growth. In both, the roots push horizontally, through the cortical tissues just above the callus but whereas in fan cuttings they continue to grow almost horizontally for some centimetres, in chupon cuttings they usually turn vertically down as soon as they emerge from the stem. In fans, the terminal bud, if present, usually grows out, together with several lateral buds, sometimes low on the stem, and the shoots tend to spread obliquely. In chupons, on the other hand, either the terminal bud, or in its absence a single lateral near the top of the cutting, grows out into a vertical leading shoot. The differences are illustrated by Fig. 2. The chupons, as might be expected, approximate more closely to seedlings in their behaviour, and the importance of that fact will be indicated later.

The essence of success with softwood cuttings lies, as every horticulturist knows, in keeping the leaves on until roots are formed, and to that end careful control must be exercised over both the water-content of the rooting medium and

the humidity of the air above. Illumination is also important, since much of the carbohydrate used in root-formation is presumably manufactured by the cuttings after they are set in the propagator. Temperature under Trinidad conditions needs no elaborate control, and none was attempted, since the object of the researches was less to discover academically optimum conditions than to establish the simplest technique consistent with practical results.

Full details of the propagating frames used and of the environmental factors studied are given by Pyke (loc. cit.). In average batches of cuttings, 50 per cent. root within three weeks, and good batches finally show 90 per cent. or more of successes. These figures justify the claim that a practicable technique has in fact been found. Subsequent treatment needs care if the rooted cuttings are to be successfully established in the field, but presents no very great difficulties.

Propagation by Layering.

Stooling and layering were tried simultaneously with the experiments on cuttings, and with equal success.

Aerial layering, or marcotting, in which ringbarked branches are surrounded by a ball of moist soil in sacking, has been found possible with cacao in Trinidad, Ceylon and Java, and is illustrated by van Hall (loc. cit). It is, however, a tedious method and for large-scale work possesses no apparent advantages over the setting of cuttings.

Pyke obtained excellent results by pegging down seedlings about 18 months old in the surface of the soil. Basal chupons of older trees, if they occur in a suitable position and are at the right stage, can be treated similarly. Under such treatment several of the axillary buds push out into vigorous chupon branches, and if they are then moulded up with soil they develop in a few months a strong root-system with one or more main roots running vertically down like tap-roots. Earthing-up must be deferred until the buds have made some growth, because cacao buds apparently will not burst when covered, and all attempts with covered layers failed. Secondary layers were at a later date made from the first with equal or even greater ease.

The observations are still incomplete in the sense that established cuttings have not yet been layered, that step being on this year's programme, but there appears no reason why chupon cuttings at least should not behave exactly like seedlings in this respect. Fan branches similarly laid down have so far given rise to fan-type layers, and fan cuttings may be expected to do the same. It is in layering of fans, however, that the plasticity of the buds assumes importance. It is most probable that by cutting hard back after rooting, or by some other manipulation, chupons can be induced on fan layers. Work is at present being directed towards finding the appropriate treatment for converting fans into chupons with certainty.

The possible advantages of layering lie chiefly in the ease of the process, and the fact that constant daily attention is not required by a layer-bed, as it is by a propagating frame set with cuttings. On this account the layering technique may prove more adaptable to estate routine and provides a means for the planter to bulk up an approved clone from rooted cuttings initially supplied by an experimental station. The possible disadvantages are the length of time required for rooting and the rather large space taken up by a layer nursery as compared

with a seedling nursery. Much remains to be discovered about the minimum time in which layers can be induced to root, and also about the number of rooted branches which can be obtained per unit length of stem laid down. Until these points are determined the method can neither be recommended for commercial use, nor accurately compared with the cutting technique in efficiency and practicability. Still, from the point of view of practical nursery multiplication, the outlook is the more promising for the existence of these alternative methods.

Stooling by a method similar to that used for Malling apple stocks has been tried, but so far has given results inferior to those from layering, chiefly because the shoots seem to need ring-barking to induce deep rooting, and the extra handling involved has no compensating advantage. It remains to be seen whether older stools will behave differently, and no final pronouncement on the relative merits of the two methods is yet possible.

Established Potentialities.

With the striking of cuttings and rooting of layers added to the previously established method of budding, there is now at the disposal of the research worker an almost complete range of possibilities of producing any kind of tree he chooses. A tree selected in the field by the plantbreeder as worth clonal multiplication may be grafted or budded on a seedling stock, or cuttings or layers may be taken from either its fan branches or its chupons, according to the circumstances, the facilities and the type of material most readily available on the tree. Once established in the experiment station, any type of tree can be converted into almost any other. Grafts or buddings can be subsequently layered or used as a source of cutting. Chupon-type plants will always produce sooner or later a jorquette of fan branches. The only gap in the chain is the absence of a sure method for obtaining chupons at will on fan-type plants, and it has been shown that this problem does not seem by any means insoluble. In short, isolation of any desired clone *on its own roots* becomes a matter of routine, and the main question next for solution is, which of the several methods of propagation available can be most advantageously adapted to the raising of planting material on a commercial scale. This question, however, involves at least three subsidiary ones of the greatest importance, which must be shortly discussed.

Outstanding Problems.

Ruling out grafting, which by the consensus of opinion of previous workers is less convenient than budding if seedling stocks are to be used, and ignoring any possible differences between cuttings and layers as means of propagating clones on their own roots, there are still six distinct kinds of vegetatively propagated cacao trees which now need careful study and comparison. They are illustrated diagrammatically in Fig. 3, which represents, from left to right:

Type IA, fan bud on seedling stock; IB, chupon bud on seedling stock.
Type IIA, fan bud on clonal stock; IIB, chupon bud on clonal stock.
Type IIIA, fan layer; IIIB, chupon layer.

The three major questions to be answered, in order of importance and urgency, are; (i) Should the root-system be of seedling or of vegetative origin? (Type I versus Types II and III) (ii) Should the root-system and the scion

be of different genotype or identical? (Types I and II versus Type III.) (iii) Should the scion be of fan or chupon origin? (Sub-type A versus sub-type B throughout). Only experiment can provide the answers, and it may well provide different answers under different sets of conditions. There are, however, a number of considerations bearing on each of the questions which must be reviewed even at the present stage, because they indicate the relative magnitudes of the issues involved.

(1) Root-systems.

The drawbacks of seedling stocks for temperate fruit trees are too well known to need more than mention. They arise from the fact that the parent trees from which the seedlings are raised are heterozygous, so that the seedlings themselves vary in constitution one from another, and the composite trees of which they form part after grafting or budding must likewise vary. The variations in yield and in other physiological behaviour of uniform scions when united with such variable stocks are of great economic significance, and it has come to be realized that if orchard material is to be truly standardized, stocks raised vegetatively must be used.

Similar drawbacks of seedling stocks for cacao are at present only assumed by analogy. Seedling cacao stocks are indubitably heterogeneous, and the argument by analogy is justifiable as a working hypothesis until disproved. A direct demonstration is difficult, first because there is so little budded cacao of which records have been kept, and secondly because there have until now been no clonal stocks to serve as standards of comparison. What little direct evidence there is does not contradict the hypothesis. Still, the direct demonstration must be provided before further work can be well and truly founded on a scientific basis.

On the other side of the account, there is a strong prejudice in many quarters in the tropics against trees on non-seedling root-systems. It is said that the absence of a tap-root makes them liable to fall in wind and otherwise militates against their efficiency. Such an argument must be respected and put to experimental test. That it may be true, yet only half true, is shown by Fig. 2, illustrating the essential differences which may arise among vegetatively induced root-systems themselves. At the present it seems likely that cacao stocks raised from fan cuttings or fan layers might be genuinely open to objection, whilst those raised from chupon cuttings or chupon layers might not. Steps are being taken immediately to compare both types very carefully with seedlings, but it must inevitably be some years before conclusive results can be obtained, and meanwhile other investigations must be pushed ahead on the presumption of an answer favorable to clonal stocks.

(2) Composition of Tree.

Assuming for the purposes of argument that vegetative stocks can be proven better than seedlings, the question at once arises whether budding remains any longer necessary or desirable. Budding of selected scions on selected clonal stocks would be directly analogous to the most advanced practice in temperate fruit culture, but it need not necessarily prove ideal for cacao, and this is a case where argument from analogy can easily be carried too far.

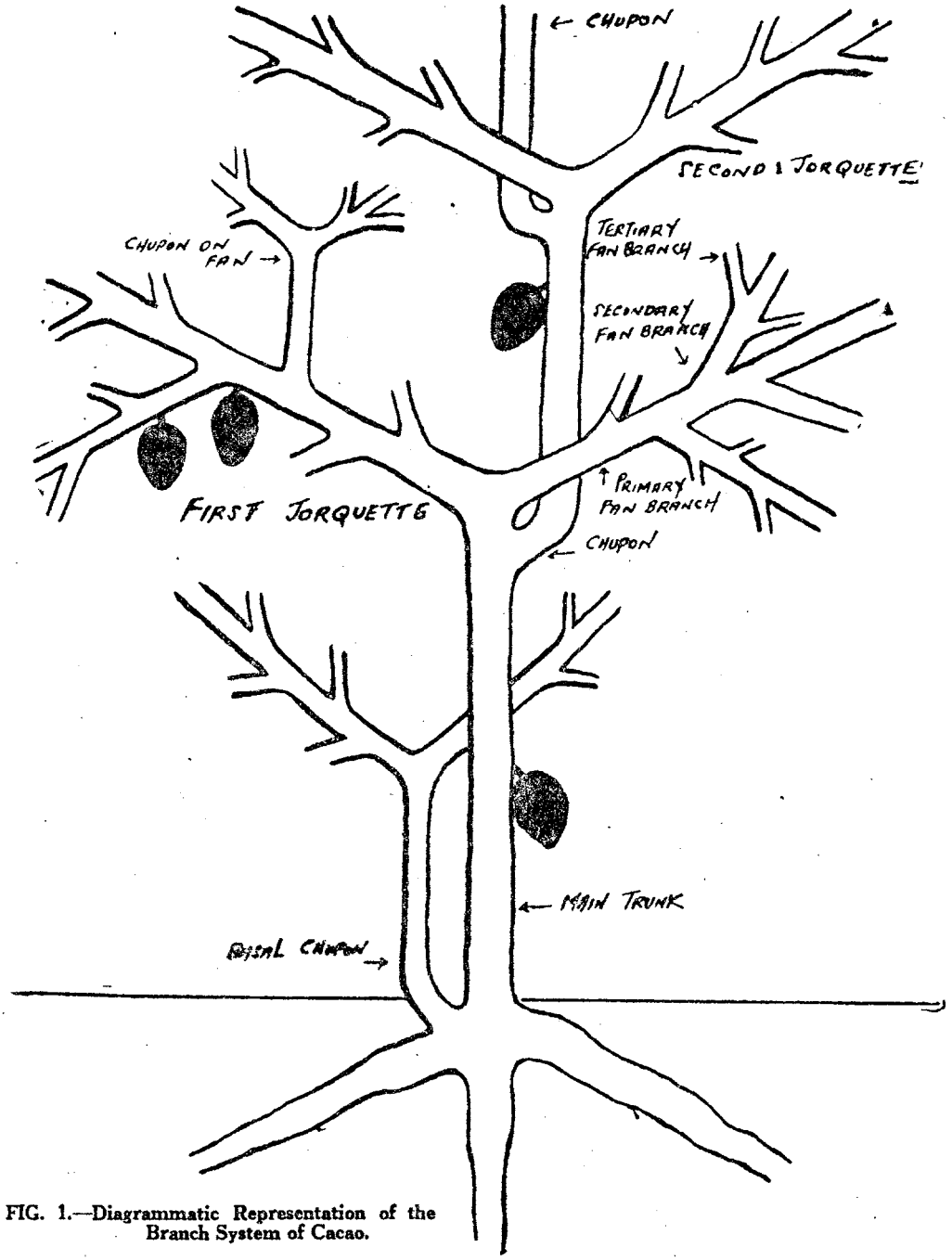

FIG. 1.—Diagrammatic Representation of the Branch System of Cacao.

Cacao trees selected for propagation will usually be selected primarily for high-yielding power, and only secondarily for qualitative characters of the fruit. In this respect they are not quite comparable with fruit varieties, which have probably in most cases been selected primarily for non-yield characters such as

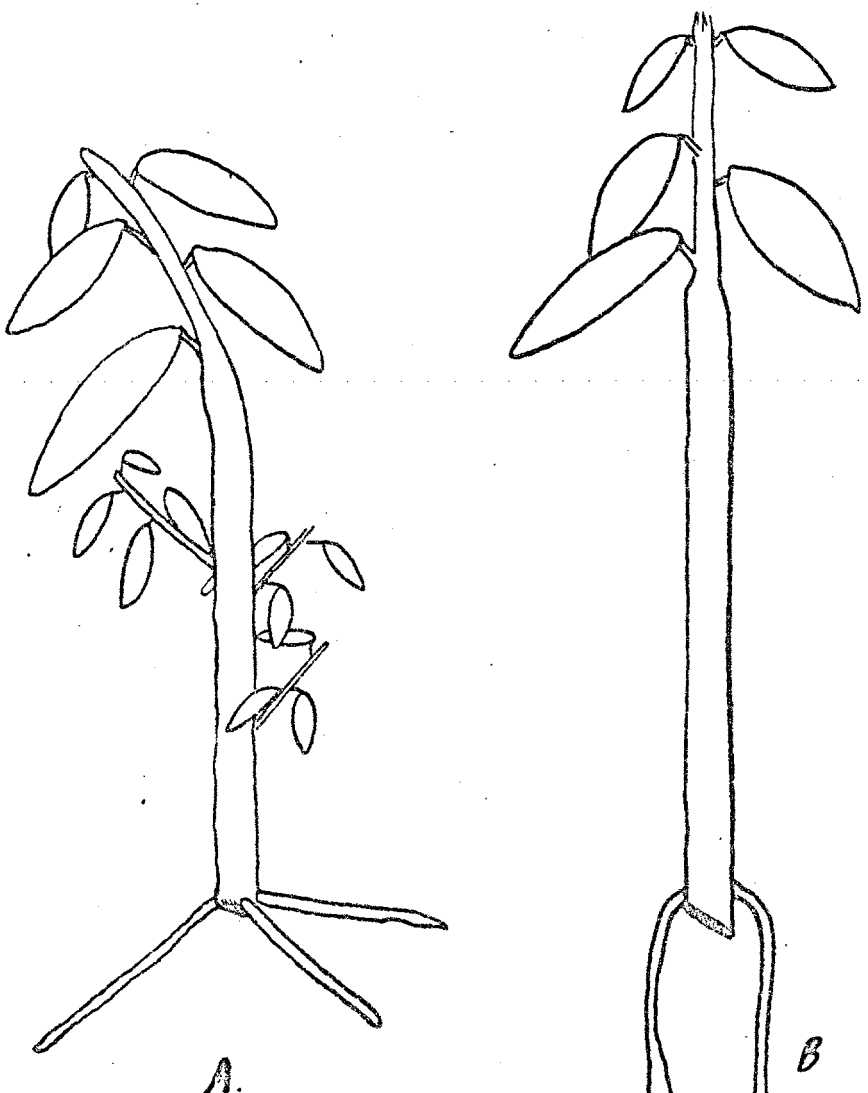

FIG 2.—A—Typical Fan Cutting.
B—Typical Chupon Cutting. (New growth only shown; old leaves omitted for simplification of diagram.)

flavour, texture, or size of the individual fruit, and only secondarily for yield per tree. The high-yielding cacao tree must have a root-system capable of supporting its yield; and if cuttings or layers from it regenerate a root-system of similar type, the main object of vegetative propagation will be attained.

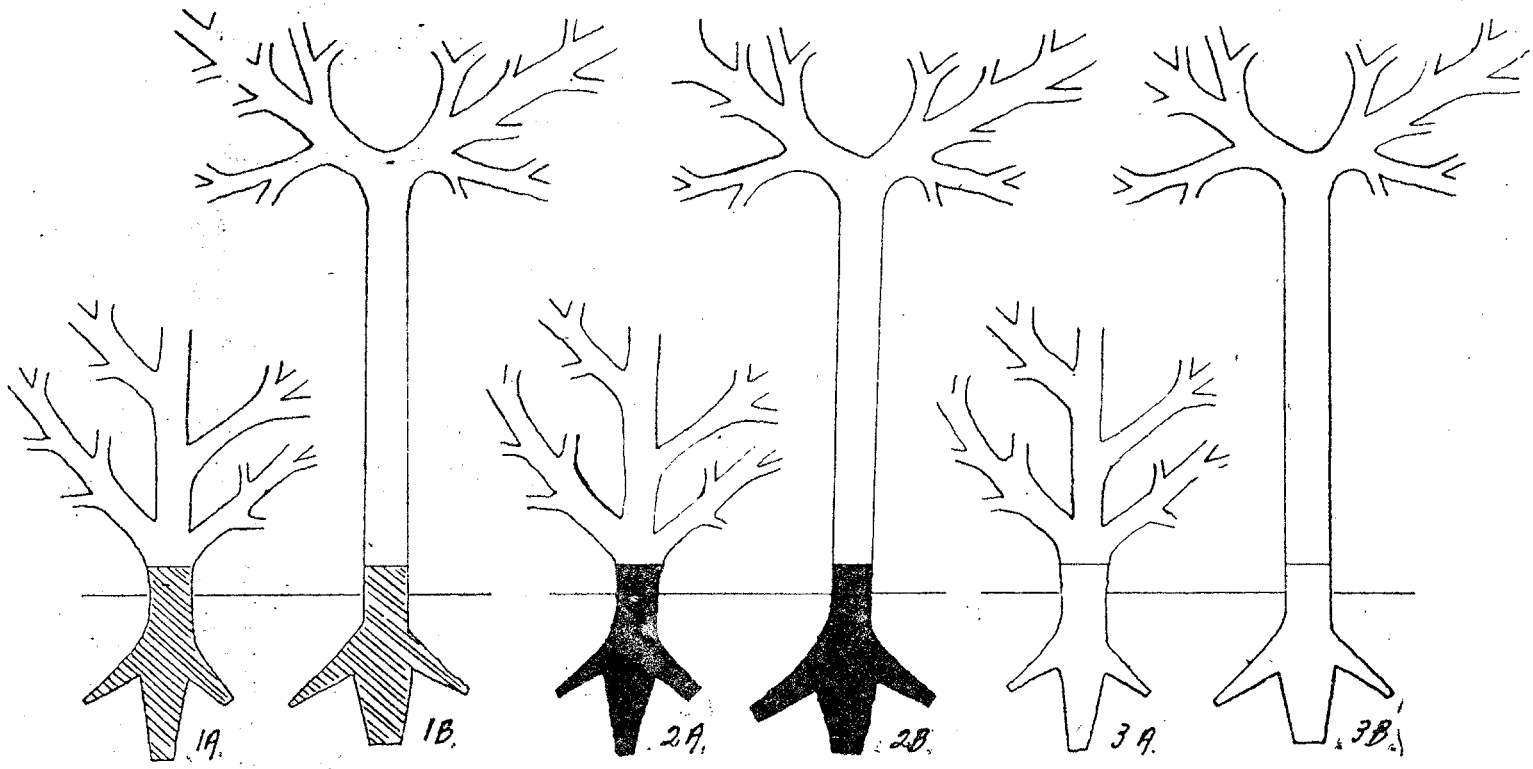

FIG. 3.—Types of vegetatively propagated Cacao trees:
1. Budded on seedling stock. A. Fan bud. B. Chupon trees.
2. Budded on clonal stock. A. Fan bud. B. Chupon bud.
3. Unworked. A. Fan cutting or layer. B. Chupon cutting or layer.

It is not overlooked that a scion good on its own root-system might give even better results than its parent if placed on another; neither have the possible uses of different stocks to change the habit of the scion been forgotten. Dwarfing stocks, for example, might be very valuable for "filler" trees in laying out new plantations at a wider spacing of the "permanent" trees. There is, indeed, scarcely any limit to the amount of research which will be needed into the interaction of stocks and scions in cacao culture, now that clonal stocks are available for accurate studies.

At the same time there is a factor of quite another kind which cannot be excluded from this part of the discussion, and that is disease. Canker (caused by *Phytophthora Faberi* Maublanc) is one of the most destructive of diseases of cacao, and causes incalculable losses. It is one of the advantages of the seedling cacao tree that, should the main trunk or jorquette be badly attacked, the whole system can be regenerated by allowing a basal chupon to grow, and it has been pointed out above that this practice is regularly followed. A budded tree naturally cannot be regenerated in similar fashion, because if a basal chupon grows it is of the stock and not the scion variety. A tree from a layer, however, will behave in this respect like a seedling. The natural regenerative power of the cacao tree is a valuable economic asset not shared to the same extent by the majority of species usually budded or grafted, and may possibly prove the deciding factor between "foreign" and "self" root-systems, at least in many districts where canker is especially rife.

(3) Branch-systems.

It has already been hinted that if layers (Type III) should ultimately prove the most satisfactory means of propagation, as on the balance of available evidence seems not unlikely, the choice between fan and chupon material for multiplication is likely to be decided by the nature of the respective root-systems. If, however, trees of Type I or Type II prove preferable, the question of branch-systems will add itself to the more urgent ones already discussed.

On account of the cauliflorous habit of cacao, if a main trunk is required on a budded tree it must be obtained from a chupon bud set low on the stock. The alternative method of budding high with a fan bud and allowing the stock to form the trunk is impracticable, because the stock would then bear fruit, and the crop would be only partly derived from the scion variety. Consequently, the choice of bud seems to be essentially a choice between presence or absence of a main trunk, and this would appear to depend more upon the tastes of the planter and the kind of cultivation he intends to give the trees than upon fundamental botanical considerations. Sub-types Ia and Ib are already both grown on a small scale with success, and whilst there is undoubtedly scope for experiments to compare the two, the problem seems both less urgent and less difficult than either of the two foregoing.
