PLATE I.—*Young cacao grown from cutting at Keravat.*

CLONAL CACAO AT KERAVAT.—I. *

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Since 1947, work designed to improve the standard of planting material of Theobroma cacao has been carried out at the Lowlands Agricultural Experiment Station, Keravat, New Britain. This paper deals with one aspect of the improvement programme—vegetative reproduction of high-yielding, high-quality cacao, with particular regard to cuttings. It discusses the use, background and establishment of cuttings and has been written specifically for commercial growers who are now in a position to obtain limited supplies of some Keravat clones. Pitfalls for growers attempting to use cuttings from their own selections are emphasized, together with notes at some length on establishment, in which stress has been placed on the degree of care necessary for success.

NEW Guinea Trinitario cacaos are highly heterozygous in nature and cross-pollination between trees is widespread. The result is that these cacaos do not "breed true". Bridgland (1959) has drawn attention to the scope for improvement and the great variation in yielding ability within seedling plantings. For this reason, the large-scale multiplication of trees, selected for high-yielding ability, together with apparent requisite quality features, has been

* Part II of this paper will appear in a subsequent issue of the *Papua and New Guinea Agricultural Journal*. It will be concerned mainly with the actual rooting process and will include reports of experimental results to date, particularly on hormone-type rooting stimulants, choice of planting material, hardening methods, potting media, pot types, and other miscellaneous data.

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undertaken by means of cuttings. Cuttings have exactly the same inherent yielding and quality potential as the original seedling from which they are taken.

Probable Role of Cuttings in Territory of Papua and New Guinea

Bridgland also states that the ultimate aim of the improvement work at Keravat is to produce both "clonal" and "hybrid" cacao seed to meet high standards of yielding ability, precocity, quality, etc. However, he has also indicated that there should be distribution of carefully selected and tested cuttings from Keravat. Such distribution is regarded by this Department mainly as a stop-gap towards plant improvement until the above-mentioned seed becomes available. When seed capable of performing as well as cuttings is produced, its economic advantages will eliminate the use of cuttings in commercial plantings.

Warning to Growers

As the whole basis for attaining greatly improved yields by means of cuttings lies in the long-term programme which goes into the selection of the original seedling trees, growers are specifically advised against attempting to use cuttings from their own selections in endeavours to improve their planting material.

Most planters do not have accurate records of the amount of cocoa that particular trees have yielded, nor have they the facilities for estimating skin percentages, cacao butter-fat contents, bean size and bean defects, all of which have tremendous value from the manufacturer's point of view. Trees selected and propagated with defects in bean quality could substantially affect the price received for beans produced.

Additionally, there is the question of compatibility of pollen. In some self-compatible trees, it appears that self-pollination may lead to the production of defective beans. Self-incompatible trees, which form a high percentage of our cacao population, normally require pollen from a self-compatible tree to set fruit. Large monoclonal blocks of self-incompatible trees would therefore set no fruit unless suitable pollinators were present. Investigations concerning this and allied points are being carried out.

Differences between selected seedlings and cuttings taken from them are also frequently observed (see below). These differences may be due, among other things, to faulty or biased selection methods, such as selection of trees growing under highly favourable competitive conditions or on particularly fertile patches of soil. Yields are thus unduly inflated by environmental factors rather than by the inherent factors in which the selector is really interested. Cope (1951) put forward an explanation for these differences on the basis of comparative root efficiency, but whatever the reasons for the differences it is an established fact that they exist. This makes it absolutely necessary for adequate testing of the selections actually grown as cuttings before expected performances may be predicted with confidence.

Finally, differing performances of clones under varying climatic and soil conditions are almost certain to occur. For this reason Keravat clones have been established for testing at Kubu, near Sohano, on Bougainville, and trials in other centres are projected.

Specific Examples of Seedling/Cutting Differences

The original Keravat selection K17-101 at nine years was only 10 to 12 feet in height and, although precocious in yield, the vigour left much to be desired. The lack of stature was acompanied by sparse foliage with only small leaves. The tree was also being suppressed to a marked degree by vigorous surrounding trees. However, cuttings of this selection were found to be among the most vigorous of our clones. At three years, they are approximately equal in size to the original seedling and are commencing to bear well.

Conversely, cuttings of K24 and K4-101, both large and vigorous as seedlings, have made lamentable growth, being less than five feet in height with only a few weak branches at two and a half years and improving little with time. Such selections, although of use to Keravat in the breeding programme, could never be considered as commercial clones.

The K1 selections, three in number, yielded well and reasonably early as seedlings, and their cuttings proved easy to root. The selections have made excellent growth and from the nurseryman's point of view they are ideal. However, these cuttings are apparently rather late in maturing, a marked defect in those plantings where an early return is an economic necessity.

For plantations with established mature crops providing an income, this would not be regarded so seriously if total yields over the economic life of the trees were comparable with more precocious clones.

These examples illustrate the need for adequate yield testing before large-scale plantings are undertaken, and they substantiate the advice given to growers not to use cuttings from their own selections.

ESTABLISHMENT OF A CLONE

Bridgland (1959) has recently described the aims and methods of cacao improvement at Keravat.

Simplified, the production and eventual release of a clone follows along the general lines described below.

Selection of a seedling tree with desirable yielding and quality characteristics. Cuttings are taken from this and planted in—

Material Nurseries which are lines of cuttings from the selected tree grown under suitable conditions (See Part II), simply to supply large quantities of cuttings for mass production and planting in—

Clone Testing Blocks (a self-explanatory term). Here the clone's performance will determine its future and the clone will be either—

Discarded due to poor yield, vigour, quality or pest resistance defects, etc.

or

Retained, having satisfactorily met the stringent requirements laid down. Once a clone comes within this category, it may then pass to the grower.

Spacing and Pruning of Cuttings

Trials involving five different spacing treatments, each pruned and unpruned, have been established, but until precise data are available,

PLATE 2.—*Young seedling. The trunk with branches arising well above ground level is quite clear.*

PLATE 3.—*Young cutting carrying an early crop. Note branches arising at ground level.*

PLATE 4.—*Straggly habit. Harvesting could be a problem. If pruning was adopted, this would involve removal of very high proportion of foliage.*

no concrete recommendations can be made. However, from experience gained to date, it seems probable that hedge-type spacings will prove to be the most suitable for cuttings. Particular spacings being examined include hedges 18 feet apart with the cuttings four feet and six feet apart within the row.

FORM OF GROWTH

Most planters have observed that cacao trees have dimorphic branching, that is, two types of branches, each with a typical leaf arrangement.

As a seed develops, it produces a single stem, the chupon, which becomes the main trunk of the tree. The leaves on the chupon form a spiral, approximating eight leaves for every three turns around the branch. The chupon forks into three to eight branches at the jorquette, usually forming a wine-glass shape. These branches are "fan" branches and have their leaves arranged on a single plane and alternately opposite. The jorquette may arise at 2 ft. 6 in. to 9 ft. or more above ground level, the height being largely a genetic characteristic of the tree, but it is commonly around 3 ft. 6 in. to 4 ft. 6 in.

All Keravat cuttings are taken from "fan" material and this results in a totally different form of growth. Perhaps the simplest description is to say that a fan cutting looks like an ordinary seedling without a trunk, the branches arising at ground level, with the qualification that at least in the early years there is a greater number of branches (Plates 2 and 3).

This habit could result in accessibility problems and is one reason why hedge spacings will probably prove most suited for cuttings. On one area at Keravat, now three and a half years and planted at 12 foot square, the clones have formed an almost impenetrable thicket, but it must be realized that this area has been deliberately left unpruned. Another area, now seven years, and planted at 12 feet on the equilateral triangle, has been pruned and is reasonably accessible, but the effect of pruning on yield is not assessable on this area for technical reasons.

Variations in Form of Growth

Wide variations in the form of growth from clone to clone are evident. These variations fall mainly into four categories :—

(*a*) Straggly, many branches growing along the ground ;

(*b*) Most erect, with few branches, and growing quite tall ;

(*c*) Compact and bushy, branches frequently just above ground level, with a neat appearance ; and

(*d*) Branches widespread, 45 degrees or less from the ground, with a markedly open centre to the bush.

The effect of the form of growth on future pruning and spacing treatments remains to be determined. The form of growth will also affect, to some extent, the period before the cutting commences to shade out the weeds at its base.

ESTABLISHMENT OF ROOTED CUTTINGS

The grower wanting to use cuttings must realize that they are extremely valuable in potential yielding ability and expensive to procure or produce. He should therefore be prepared to take considerable trouble with the cuttings, particularly in the first 12 months after planting. During this period they are not nearly as vigorous as seedlings and require careful nursing. Apart from the economics of losing expensive planting material, it is emphasized that the treatment which a cutting receives in this period will almost entirely determine its future performance. Rough methods which, although not ideal, can be " got away with " when using seedlings, will certainly not do for cuttings. They will result in disappointment and financial loss. Shade requirements must be strictly adhered to and planting techniques should follow closely the details given below.

PLATE 5.—*Compact, bushy, neat appearance.*

PLATE 6.—*Erect habit. This cutting is about* 10 *feet in height.*

Transport of Cuttings Within Gazelle Peninsula

(For bare root transport away from this area, see Part II.)

The aim here is to move the cuttings with as little disturbance of the soil-root association as possible, and to minimize the physical damage and water loss on leaves, due to wind. The cuttings should best be moved in the cool of the evening, or during light, showery weather. Excessive speeding and jolting of vehicles must be avoided. All cuttings are sent from Keravat in baskets at present (see Part II—Polythene Bag Technique) and these should be tightly packed together. It is an advantage to have three or four inches of levelled sand on the bottom of the truck, as this reduces movement of baskets appreciably and probably assists as ballast.

Upon Receival

A shaded area allowing 25 to 30 per cent. of well-dappled natural sunlight, where the cuttings can be watered, is necessary for the first few days. Should prevailing weather allow, a slight increase in light intensity is permissible. One fairly good soaking designed to refirm the soil around the roots immediately after receival is advantageous. For the next few days, very light but frequent applications, as with a knapsack spray, are required, using only sufficient to moisten the leaves.

The open-sided nature of the baskets, the spreading type of root system and the very light soil supplied make it imperative to ensure that baskets are not allowed to dry out at any time. This will result in desiccation and death of the roots.

No fertilizer applications should be made because—

(1) Fertilizer is unnecessary with the type of potting soil used ; and

(2) There is danger of damage resulting from injudicious methods of application and/or excessive quantities or concentrations.

Leucaena glauca is a most suitable shade source during this holding period.

Stage for Planting

Provided that a cutting has successfully hardened off two flushes (i.e., has six to 10 hardened leaves) it is regarded as satisfactory for planting out under Keravat conditions. Such a stage is normally reached 12 to 15 weeks after the cuttings have been first set in the propagating units. Larger cuttings can be quite readily planted out, but for reasons discussed below (under 2) care should be taken to ensure that serious rotting of the basket does not occur.

Rebasketing, as carried out so frequently overseas, is a very costly process, and is not favoured at Keravat. With the excellent growth made here, combined with the earlier stage of planting employed compared with overseas, it should be unnecessary.

Planting Out in Field

Losses immediately after planting, if any, should seldom exceed one and a half to two per cent. and with some attention to detail, may frequently be eliminated. Factors affecting post-planting losses include—

(1) *Weather.* Experience has shown the advantages of planting in the rain. Planting in drier weather may be done but, without close attention to 2 and 3 below, increased losses may result.

(2) *Undue Disturbance of the Potting Soil.* This can be quite serious, the end effect being a severe water deficiency in the leaves, with subsequent death of the leaves. Cacao cuttings with all leaves lost invariably die. The sensitivity of cacao leaves to water losses has been described at Turrialba (1952) and once the soil-root association is seriously interfered with the major source of moisture to the plant is lost. Baskets, when being moved to planting holes, should therefore be supported on the hand and not merely carried by the top of the basket.

(3) *Removal of the Basket.* Baskets are made of several species of "bush rope" (species undetermined) and the ribs are of *Donax grandis,* a common bush plant. Under no circumstances, regardless of the apparent "rottenness" of the baskets in older cuttings, should the cutting be planted without the prior removal of the basket. Observations, together with the digging up of a number of cuttings, have demonstrated a marked restriction of root development when basket and all has been planted, resulting in bench rooting and falling over of trees. A

PLATE 7.—*First step in planting. The basket is carefully cut down one side and across the bottom.*

PLATE 8.—*The undisturbed ball of soil is carefully removed from the basket.*

secateur should be used to cut carefully down one side and across the bottom of the basket. The sides should then be pulled apart and the undisturbed ball of soil removed. (See Plates 7 and 8.)

(4) *Level of Planting.* The practice (commonly observed with seedling plantings) of planting in a saucer-shaped depression should be avoided and care taken to see that the soil at the base of the plant, after being firmed down, is level with the surrounding soil.

(5) *Snail Baits.* Always use paper baits (Bridgland and Byrne 1958) in areas infested with the Giant Snail, *Achatina fulica.*

(6) Care should be taken to see that shade is not excessive in the planting block. This is largely a matter of judgment and experience. Excessive shade inhibits bud development, whereas excessive light results in dwarfing, chlorosis and sometimes death of the foliage.

Care in the First 12 Months

All cuttings should be carefully ring weeded *by hand* at intervals short enough to ensure that they do not have to compete too strongly with weeds for water and nutrients. The differences in nature of the root systems, together with the large initial discrepancies of relative height increases of cuttings and seedlings of cacao, make a more frequent weeding of cuttings necessary for at least the first 12 months.

The root system of a cutting for this period is largely confined to the first inch or two of soil, rendering it particularly susceptible to damage by hoes, knives, sarifs, etc. The root system of a seedling is initially of a less widespread but far deeper type, with a definite tap-root.

It may be as well at this stage to answer a frequently asked question—"Does a cutting have a tap-root?" Strictly speaking, the answer is "No". However, we have observed at Keravat, in a number of cuttings planted as recommended above and later dug up, that a large root, or roots, up to two or three in number, has taken over the role of a tap-root. At three years of age there is no apparent difference in size between the genuine seedling tap-root and the "pseudo" tap-root of the cutting.

Early height differences between seedlings and cuttings also make it necessary for frequent weeding, unless the cutting is to be "buried" under weeds, and so starved for light. At 12

PLATE 9.—*The cutting planted and ring-baited against the Giant African Snail.*

months of age it may be expected that a cutting will be about 2 ft. 6 in. in height, with a margin of six inches either way. By this time frequent weeding is no longer necessary. A seedling at this age could normally be expected to attain a height of 4 ft. 6 in. to 5ft. 6 in. Wide variation may be expected to occur.

Period 12 months to Bearing

With development, hand weeding becomes unnecessary. Cuttings with branches rising from

ground level provide sufficient shade for weed control around the base at an earlier stage than seedlings. Recommendations for sarifing between lines of trees and shade requirements are, until more is known, the same as for seedlings.

Pest Control

One minor pest which has attacked cuttings grown at Keravat is the longicorn beetle *Glenea aluensis*. Damage is caused by the larvae of this beetle, the eggs being deposited in the bark. The developing larvae bore into the trunks of the cutting, particularly just above ground level where several branches arise together. A gummy exudation is invariably associated with the wound.

Control measures recommended by Dun (1959) and found highly effective involve scraping away the gummy exudate and applying approximately ½-1 cc of 15 per cent. Dieldrin concentrate with a small camelhair brush (child's piant brush is ideal) directly to the wound. One gallon of Dieldrin concentrate will treat approximately 3,000 wounds.

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