THE
IMPROVEMENT OF YIELD
IN
HEVEA BRASILIENSIS

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,, 21, ,, 23 : ,, 1929 ,, 1923
,, 83, Table XXIX *read* Bark thickness in Millimetres.

THE IMPROVEMENT of YIELD IN HEVEA BRASILIENSIS

by

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INTRODUCTION

THE PROBLEM OF YIELD IMPROVEMENT

The problem of yield improvement is primarily economic and only secondarily scientific. There is little doubt that, from the earliest days of agriculture, crop improvement by some elementary form of seed selection was practised in the case of the staple food crops. The guiding principle was invariably that of an increased return at harvest or the maintenance of some special quality of product.

It was not until the beginning of the twentieth century that science began to take part in this work as the principles of breeding and selection gradually became known. The result is now that one main branch of agricultural research is devoted to the production of the best type of crop plant so that, in many crops, yields have been greatly increased or some special quality has been developed and fixed.

But during this new era also quantity rather than quality has usually been the desire of the cultivator and the aim of the research worker. That is, the problem has generally been one of yield increase and the best plant has become defined as that which produces the greatest return.

In the case of rubber we have the somewhat strange circumstance that, until quite recently, the prevailing economic conditions have militated against plant improvement and created the situation in which it was possible for a plantation of ordinary trees, crudely planted and with the minimum of tending, to give a very profitable economic result. In other words, no better planting method existed than that in which, from a sample of seed randomly gathered, 200 plants were planted to the acre and subsequently thinned out to rather less than half their number. Consequently, older planters often find it difficult to comprehend that this state of affairs, in which the minimum of effort and responsibility was combined with a solid financial return, cannot hope to continue in the future. It is here also that the reason must be sought for the prejudice, often encountered, against the more costly methods of producing an improved stand of rubber trees.

There is little doubt that the production of high-yielding types is the problem of the moment for the rubber grower. Economic forces have been massed with such effect against a high market price, bearing little or no relation to the cost of production, that the price of rubber may now be regarded as more or less stable. No new avenue of utilization is in immediate sight; manufacturers' research methods march step by step with increased demands along the present avenues; the business of purchasing is better organized; the manufacture of reclaimed rubber has become an established industry while the normal cost of production has been dragged from the region of mystery and become a known factor.

The most certain aid to a lowered cost of production is an increased yield per acre and the key to this is the high-yielding tree.

At first sight the problem may appear simple. High-yielding trees are not uncommon in spite of the fact the large majority of the trees of every plantation are low yielders. The problem is how to secure uniformity of high yield.

The fact that plant improvement is not a simple process makes the assistance of the selectionist and plant breeder essential but, unfortunately, in spite of the great advances they have been able to make in the improvement of other crops, the vast body of data and literature which has accumulated as a result is only of restricted value to one wishing to improve the rubber tree. In the latter case the conception of yield is a special one, for the product—latex—differs fundamentally from the crop of other plants. Furthermore, the rubber grower is concerned almost entirely with quantity and the question of quality barely arises.

Nevertheless, there are distinct prospects of yield improvement by following the well-established methods employed by the selectionist and plant breeder with other crops. These methods fall into three classes:

(*a*) Vegetative propagation or the multiplication in clones of the best types of a variable population. The multiplication is carried out by budding and the sexual part of the plant plays no part in the process. That is, the buddings are identical genetically with the parent tree from which they were made. Other methods of vegetative propagation, although successfully employed with other woody plants, may be excluded from consideration. The production of marcots is possible and these may at times have a limited use for experimental purposes but multiplication by means of cuttings is impracticable; (*b*) Seed selection; and (*c*) Hybridization or breeding.

In employing the term "improvement," the increase of yield which can be obtained through amelioration of the soil conditions is not included.

An improved type is as susceptible to climatic and soil influences as the normal and can only give maximum production under optimum conditions. The provision of these, however, is the work of the soil chemist and physicist. The selectionist and plant breeder are concerned only with the inherent productive capacity of the tree, that is to say, their work begins where the work of the former finishes.

In 1928, the author published a small manual on the budding of Hevea. Written hurriedly and, in a sense, reluctantly, to meet a popular local demand, its success has deepened the author's feeling of regret that it was necessarily out of date when published. In view of the considerable advances that have been made during the last two years, especially in the Dutch East Indies, this work has therefore been completely revised and incorporated in the present volume.

All the signs point towards a great increase in the employment of budded stock during the next few years, but already it is possible to see the limits of fundamental research on budding. It is true that much work remains to be done on clone testing and on the development of suitable tapping methods for buddings but, during this period of increased practical exploitation of the budding method, research will become increasingly more applied to the subjects of seed selection and breeding, until the position is attained where budding is merely the hand-maiden of both.

The author offers the present guide to the selection and breeding of Hevea in the hope that it will not only form a reliable survey of the position up to date but also encourage planters to try out in the field the methods it outlines as practicable in an ordered programme of economic plantation development.

The figures in parentheses appearing in the Text refer to "List of Works referred to," *see end of each Chapter.*

CHAPTER I

BUDDING

I.—The Introduction of the Method

More than a decade has passed since the earliest experiments on the budding of Hevea but it is only during the past two years that it has become possible to survey the progress made by scientific research on the method and to estimate the economic advantages accruing from its employment in ordinary plantation practice.

Even to-day budding is regarded by many planters as an accidentally or arbitrarily introduced method which has no place in normal planting procedure, although a survey of the history of its development shows this clearly not to be the case.

It was not until twenty years after the introduction of the Wickham seedlings in 1876 that the cultivation of Hevea on a plantation scale was seriously commenced in Malaya, and for some years attention was almost exclusively confined to methods of cultivation and tapping and of treatment of the latex after collection. Later on fungus diseases made their appearance and it became necessary to enlist the services of the mycologist to work out methods for controlling these. Progress having been made towards this end attention gradually became directed to the importance of a logical system of thinning out based primarily upon the tapping test. Research work both in Java and Malaya showed early and definitely that when a Hevea population was raised on an estate by normal planting methods from an ordinary delivery of seed, the individual trees would be found to vary widely in productive capacity when they came into tapping. Moreover, the greater number would be found to give yields less than the average for the whole field, while an undue proportion of the crop would come from a relatively small number of high-yielding trees.

The results of different investigators agreed closely so that it will suffice to record for the Federated Malay States that Whitby found, in a population of 1,103 trees, 28% of the total yield to be given by 9.6% of the trees.(1)

The possibility of detecting the potential high-yielders, at as early an age as possible, became regarded as of paramount importance and about ten years ago several research workers in Java, Sumatra and Malaya began to inquire whether high-yielding capacity might not be related to some measurable vegetative character of the tree, e.g., girth of trunk, thickness of bark or number of latex vessel rows. Unfortunately, owing to negative or inconclusive results little has come out of this work which is of assistance to the working planter as a guide when thinning out.

Furthermore, selective thinning-out on the basis of tapping results is seldom straightforward work. Considerations of position and spacing must all the while be taken into account and the situation frequently coped with where both high and low yielders are grouped closely together, instead of being distributed throughout the field. Complications of this kind created a demand for a method of establishing a population of potential high-yielding trees directly in the field when planting.

Two possible methods of achieving this desirable result had already been considered by research workers in the Dutch East Indies. Reasoning by analogy from the immense improvement which had been obtained in the case of cinchona, sugar and coffee, one set of workers directed its attention to the selection of seed from known high-yielders whilst a second contemplated the possibility of grafting on to suitable stocks buds which should transmit the high-yielding character of the mother tree.

At first these two lines of investigation were pursued independently but, as will be shown later, research workers have found unexpected advantages in a combination of both, and budding has been shown by workers in Java and Sumatra to be an indispensable auxiliary in work on seed selection.

This new development in rubber research in the Dutch East Indies is easy to understand. Striking results had already been obtained by Dutch agricultural research workers in the improvement of coffee, tea, sugar and cinchona by methods of selection, breeding and grafting. In the case of coffee they had succeeded in producing a type capable of resisting the pests which at first threatened the successful establishment of this crop; by grafting Cinchona Ledgeriana upon *C. succirubra* they had produced a plant with an alkaloid content great enough to enable powerful economic factors in the quinine market to be overcome while the work of the Sugar Research Station on the selection and breeding of high-yielding types had been crowned with equal success.

From all these advances the plantation industries concerned had greatly benefited and there is no doubt that results of such economic importance must have greatly stimulated and encouraged both research workers and planters to attempt to apply similar methods to Hevea.

The honour of being the first to investigate the possibility of budding Hevea belongs to van Helten, the present superintendent of the Economic Gardens at Buitenzorg, who made preliminary attempts in 1910-13 which met with little success. Under the guidance of Cramer budding was, however, resumed in 1916 with immediate success and Cramer began forthwith to popularize the method advising planters to try it on a small scale in order not to lose time. In 1918 van Helten published an account of his work and technique[2][3] and interest was at once aroused outside the Dutch East Indies.

It is gratifying to record that estates in Java and Sumatra took rapid steps to investigate the method. On the now famous Pasir Waringin Estate Holle had already commenced in 1915 a systematic tapping record of all tappable trees as a result of which in 1917 he was able to select 25 of the best possible mother trees for budding. Operations were commenced in 1917 with small success but in the following year they were more successful both in the nursery and field. As a result, these oldest budded fields now comprise about 55 acres while the number of clones is 19.

In 1918 buddings from ten different mother trees were sent from Pasir Waringin to Bodjong Datar Estate, also in the Bantam Province of Java, and were planted out in a 36-acre block. In this work the plantation managers Bodde and Tas were associated in co-operation with Cramer.

Side by side, Bobilioff had carried out an elementary investigation of the process of union between bud-patch and stock and as a result the method of patch budding was advocated in preference to the inverted T-method and the method of Forkert.[4] The first buddings to be carried out by the

H.A.P.M. in August, 1918, were from mother trees selected according to their yield records from the general estate population.[5] In November of the following year ten acres of buddings were planted out from nurseries.

In late 1918 and early 1919 the A.V.R.O.S. Experiment Station also made a start using buds from known high-yielding mother trees on various East Coast estates and, in this connection, an important fact seems to have escaped notice, namely, that so far as their origin has been described, most of these mother trees were from Malayan seed.[6] This fact gives solid ground for the expectation that mother trees exist in Malaya which are at least as good as those hitherto discovered in the Dutch East Indies.

In February, 1921, Vischer[7] published a preliminary account of the work on Pasir Waringin with special reference to the relation between yield and the girth and number of latex vessel rings respectively. In the case of the two clones PW 34 and PW 217 he showed that the vegetative development was quite satisfactory but the variability of yield was greater than expected. Vischer suspected that in some of the plots mixing of clones had occurred during planting out, a fact which was confirmed later when it became possible to identify different clones by means of their seed and vegetative characters.

Later in the same year came the first published news that the research staff of the H.A.P.M. in Sumatra had been devoting considerable attention to budding and that great advances of plantation method had been made by them in the direction of the selection and testing of mother trees, lay-out of nurseries, training of labour and costing of budding operations.[8]

It is perfectly clear from the above that budding was no capricious or accidental introduction to the rubber plantation but a logical step in progressive plantation practice, which a small number of commercial undertakings in Sumatra and Java were willing to test, confident in the recommendation of its value by their scientific advisers.

It is therefore interesting to compare the contemporary position with respect to the exploitation of the method in Ceylon and Malaya as shown by the published literature on the subject, remembering, however, in the case of Malaya, that there has been a considerable amount of private effort the results of which, unfortunately, have never been placed on record.

In November, 1919, the editor of the *Ceylon Tropical Agriculturist,* as a result of information obtained from "recent publications in Java," discussed the possibility of increasing yield by adopting the budding methods of Java and Malaya. Experiments were started at the Royal Botanic Gardens, Peradeniya, in 1919 with no success and evidently a watching attitude was adopted until August, 1921, when the Ceylon Rubber Research Scheme issued a circular advising estates to investigate the usefulness of the method. About the same time experiments were apparently restarted by the Department of Agriculture and in September, 1921, seven successful buddings out of twelve attempts were obtained at Peradeniya.

In Malaya the position was a little further advanced: preliminary experiments were instituted by the Department of Agriculture early in 1919 and, after interruption, were resumed in August, 1920. Milsum, the officer responsible for this work, also visited the Sumatran East Coast and on his return, published in 1921 a practical illustrated account of the method for the guidance of planters.[9]

The progress made by the method up to the end of 1921 may be briefly summarised, therefore, by stating that whereas both in Java and Sumatra three- or four-year old buddings were available for investigation, Malaya had just begun seriously to experiment, while Ceylon had, as yet, barely made a start.

It might also be mentioned that in 1921 the first handbook on the technique of budding and grafting was produced by Tas,[10] the chief administrator of the Pasir Waringin undertaking. This is on roughly the same plan as the well-known handbook by Gough.[11]

II.—Further Development of the Budding Method

The history of the period subsequent to 1921, which has seen the establishment of the budding method in progressive plantation practice, is a record of active experiment both by research workers and plantation managers. One of the most encouraging features of the work in the Dutch East Indies is the constant evidence of cordial co-operation between the plantation and research staffs, the result being that, to mention but a few, the estates of Bodjong Datar, Pondok Gedeh, Tjirandi and of the Anglo-Dutch Plantations of Java now stand as striking examples of the economic advantages gained by adopting a progressive, far-sighted policy based upon the results of scientific research.

(*a*) *The Pasir Waringin Clones.*

In 1922 Vischer published an account of the further progress made by the buddings on Pasir Waringin by the time they had reached the age of three and a half years.[12] In the case of clone PW 34 the increase in the number of latex vessel rows during the preceding year was from 7 to 12, which was much better than the development shown by sets of four and a half year old seedlings from two other mother trees. Girth development was slightly smaller but the relation between girth and number of latex vessel rows was much more definite than with the seedlings.

The chief conclusion arrived at, however, was that up to the fourth year the vegetative development of the buddings was uniform and quite satisfactory.

So far, then, the published work on budding does not appear to be more than sufficient to give encouragement to the experimenter so that it is of interest to note the revelation by Mr. Victor Ris, a Visiting Agent of Medan, of the fact that the A.V.R.O.S. Research Station had already in June, 1922, supplied to its members about 6,000 metres of budwood.[13]

Towards the end of 1922 Vischer and Tas[14] were able to supplement previous reports by giving the first results of tapping the Pasir Waringin buddings which were then four and a half years old.

Before going on to describe these it is necessary to state that in the following portion of his memoir, unless stated otherwise, the yield of a tree will be expressed in pounds of dry rubber per annum, assuming the tree to be tapped 160 times during the year. This is an arbitrary choice but there is considerable difficulty in deciding upon a standard of comparison which will enable a planter to gain an immediate impression of the productive performance of a tree and the above has been adopted as the best standard. By multiplying the figure by 108 an estimate may be gained of the yield per acre of buddings planted 20 ft. by 20 ft.

The four clones of Vischer and Tas now to be considered are PW 34, PW 225, PW 2, and PW 217. The mother trees had already all been attacked by Brown Bast, the first three in 1919 and the fourth in 1918, but in the year previous to this attack the yields at the age of nine years had been as follows:

PW 34	. . . . . .	13.2 lb.
PW 225	. . . . . .	17.1 „
PW 2	. . . . . .	15.8 „
PW 217	. . . . . .	16.5 „

In one field, mixing of clone had occurred so these will be left out of consideration altogether and attention confined to PW 34, PW 2, and PW 225. About 100 of each clone were tappable and from the July records of grammes of dry rubber the annual tree yields for the three can be calculated as:

PW 34	. . . . . .	2.65 lb.
PW 2	. . . . . .	1.55 „
PW 225	. . . . . .	0.84 „

These figures are not abnormally high but the yield of the best clone, PW 34, was much better than that of an ordinary planting from seed, one and a half years older, on the same estate. The other clones fell below this level.

One of the results was the demonstration for the first time of the great uniformity of yield throughout a clone; for example, in PW 34, out of the 93 trees tested 70 gave yields between 2.1 and 2.8 lb.

Another important result was the demonstration that, however careful the testing of the mother trees may have been, success cannot be guaranteed in every case. For example, the high productivity of the mother tree of PW 225 could not be transferred to the buddings and was probably due to some external factor such as a more favourable soil condition or attack by disease.

A further conclusion established by Vischer and Tas was that the productivity of the buddings was in close relationship to the girth, bark thickness and number of latex vessel rows of the individual trees. This means that in an area thickly planted with a single clone, thinning out could be done at one operation on a basis, for example, of girth alone.

There is no doubt that many persons regarded these results on Pasir Waringin as disappointing and a considerable body of adverse criticism of budding began to develop, both in planting and scientific circles, the effects of which are encountered even to-day. Strictly speaking, however, this has not been entirely detrimental to progress except in Malaya and Ceylon for, as a result, experimental work has become more carefully planned and results more carefully analysed. The highest testimonial to the value of the method has been its recent description as a menace to the industry.

In 1924 evidence began to accumulate more rapidly, for in that year the results obtained by Cramer at the Cultuurtuin, Buitenzorg, and Heusser at the A.V.R.O.S. experimental grounds became available to the public.

(*b*) *The Bodjong Datar Buddings.*

The tapping of these clones began in 1922, the results in the first place being regarded as disappointing. The yield of the whole budded area did not exceed that of ordinary seedlings, amounting only to 296 lb. per acre. Closer analysis of the plots, however, showed remarkable differences between the individual trees and separate plots, and in 1925 the organization was begun, in co-operation with the Proefstation voor Rubber, of the series of tests which have led to the identification of the now famous Bodjong Datar clones. These tests are dealt with on page 26.

(*c*) *The Avros Clones,* 1919-23.

In January, 1924, Heusser published an account of the first tapping of 26 of the principal A.V.R.O.S. clones.[15] The mother trees of these had been discovered from the results of tapping records taken on a number of estates on the Sumatran East Coast and it is important to note that a number of these trees were definitely recorded as having come from Malayan seed. This is emphasized once more to correct erroneous opinions widely prevalent in planting circles; first, that in the high-yielding material discovered in Java and Sumatra there is something inherently superior to what may occur in other rubber-producing countries and, secondly, that some portion of the high-yielding character is due in some unspecified fashion to the manipulations of the experimenters themselves. Both are of course incorrect; any results obtained by the workers in Java and Sumatra have only been obtained by careful and patient testing of the best material to hand and there is no *a priori* reason why material equally good or even superior should not be discovered in Malaya and Ceylon.

Most of the buddings were about four years old in 1923 when tapping was begun on a half cut at 50 cm. (20 ins.) from the union. Tapping was continued for 20 consecutive days and, as the trees were wintering at the time, it was considered that the yield figures would be lower than normal.

The first clones to be tapped were growing in special fields on different estates scattered along the East Coast and were divided by Heusser into two classes "A" and "B." Class "A" contained the well-proved clones and particulars of these are given in Table I.

Reckoning 108 trees to the acre the figures in the last column correspond to yields ranging from 308 lb. to 120 lb. of dry rubber per annum.

Heusser's Class "B" includes seven clones which he considered either incompletely proved, or unpromising. These will be left out of consideration for the moment but their numbers may be noted as 51, 8, 151, 135, 139, 152, and 35. It is shewn independently later that 51 is inferior but that 152 is one of the best clones.

TABLE I.

No. of Clone.	Age.	Girth at 40 ins.	Bark Thickness.	No. of Trees.	Average Annual yield.
52	4 years	18½ ins.	5.8 mm.	9	2.86 lb.
80	4 „	18 „	5.2 „	10	2.51 „
50	4 „	21⅕ „	6.1 „	8	2.52 „
33	4 „	15⅗ „	5.8 „	6	2.35 „
36	3 „	12⅗ „	4.9 „	11	1.01 „
49	3¼ „	11⅘ „	4.5 „	4	1.01 „

A third class "C" comprised 17 clones planted in 1919 in a special seed garden in the Perdagnan Forest Reserve. Of these six were regarded as worthless and seven as showing promise. Particulars of the latter are given in Table II, the tapping test having been carried out over 28 days only.

TABLE II.

No. of Clone	Age.	Average Girth at 40 ins.	Bark Thickness.	No. of Trees.	Average Annual yield.
31	4½ years	18 ins.	—	1	1.91 lb.
60	4½ „	17 „	—	1	1.27 „
65	4½ „	17 „	—	1	1.21 „
147	4½ „	17 „	—	2	1.66 „
154	4½ „	—	—	1	1.51 „
163	4½ „	17¼ „	—	4	1.63 „
174	4½ „	18 „	—	4	1.65 „

Again taking 108 trees to the acre the results in the final column correspond to annual yields ranging from 206 lb. to 137 lb. of dry rubber per acre.

The balance was made up of four clones, namely 51, 80, 52, and 152. Of these No. 51 proved as poor as it had already been shown in Class "B," while No. 80 proved as good as it had already done in Class "A." On the other hand No. 52 did not show its good qualities as well as it had done in Class "A," while No. 152, of which only one example was available and which had already been placed in Class "B" as unpromising, now showed a result equal to 230 lb. per acre. These results are supported by later tapping tests.

It will be remarked that, throughout, the number of tappable trees in each clone was small, and the validity of any conclusions drawn from their behaviour comes into question at once. As, however, several further tapping tests have now been carried out on these clones this question may well be deferred until the results of these later tests are available to speak for themselves.

Heusser claimed that his results supported Vischer's statement that the yielding capacity of budded trees belonging to the same clone is uniform and increases in proportion to the increase in dimensions of the growing trees.

The girth of the individual trees of most of his clones varied considerably and the direct relation of yield to girth within a clone was very strikingly shown. It is obvious, therefore, that for buddings of equal age from the same mother tree, uniformity of yield will only be obtained when the girth of the individual buddings is uniform. The variation within one clone of the mean daily yield of dry rubber is shown in Table III and there were correspondingly wide variations of girth.

Heusser also attempted to compare the yields of his buddings with those of seedling material of about the same age which had been raised—

(*a*) from unselected seed
(*b*) from selected seed.

Comparative figures were not easy to obtain. In the first case he had access to the tapping records

TABLE III.

No. of Clone.	MEAN DAILY YIELD : DRY RUBBER.		
	Highest.	Lowest.	Mean.
52	11.18 grms.	4.44 grms.	8.13 grms.
80	13.66 „	3.30 „	7.26 „
50	10.20 „	3.76 „	7.18 „
33	7.97 „	4.13 „	6.62 „
36	4.02 „	1.10 „	2.75 „
49	4.32 „	2.09 „	4.32 „

of some 50,000 trees planted 18 ft. by 18 ft. on a well-managed estate in Sumatra and the average daily yields in grammes of dry rubber were found to be as follows:

Four-year old trees yield 1.89 grms. per tree.
Five „ „ „ „ 3.11 „ „ „
Six „ „ „ „ 5.41 „ „ „

The comparison was entirely in favour of the budded trees.

In the second place a comparison was made of the latter with illegitimate seedlings raised from the mother trees of clones 26, 28, 30, 32, 33, 35, and 36.

In the case of clones 33 and 35 the comparison was almost direct although the number of trees was small. The seedlings were about six months older than the corresponding buddings but the mean girth was nearly the same. Full particulars are given in Table IV from which it can be seen that here again the comparison was wholly in favour of the budded trees.

TABLE IV.

	Number.	Age.	Girth.	Mean Daily Yield.
Clone 35:—Seedlings..	8	4½ yrs.	39.6 cm.	2.97 grms.
„ :—Buddings..	2	4 „	42.5 „	3.97 „
Clone 33:—Seedlings..	10	4½ „	39.5 „	2.87 „
„ :—Buddings..	6	4 „	39.1 „	5.86 „

From actual experience of storm damage in two of his experimental fields, Heusser showed that the mechanical strength of the trunks of his budded trees was not lessened by their cylindrical shape. No fracture took place at the union in any of the casualties.

Grantham had already reported that the yield of a budding decreased as the cut approached the union, and Heusser, as a result of an anatomical investigation, thought that this might be due to the fact that only a proportion of the latex vessel rows of the scion connected with those of the stock while the remainder came to an end at the union. This evidence, however, was not direct so that the question must still be regarded as an open one.

The bark thickness of the four-year old buddings was generally about 6 mm., the lowest thickness recorded being 4.5 mm. and the highest 6.5 mm. Heusser considered these figures to be slightly less than those for the bark of comparable seedlings, but as far as the present writer's experience in Malaya goes, the figures Heusser gives for the bark thickness of buddings are themselves on the low side.

As against this smaller thickness Heusser found that the thickness in the tappable area did not vary greatly, while the renewal left nothing to be desired.

In the buddings both flowering and fruiting were remarkably early and profuse, which is a usual effect of budding and grafting, but no effect of the stock upon the habit of the tree could be demonstrated.

The early flowering of budded trees is likely to be of very great importance in the near future to workers on the selection and breeding of strains of Hevea, more especially where methods entailing artificial pollination are employed. By the time an ordinary plantation tree, grown from a seedling, comes into flowering the inflorescences are generally inaccessible. Only exceptionally, e.g., when the trees are either widely spaced or quite isolated, is it possible to find accessible flowers on some of the pendent side branches. Budded trees, however, often produce flowers in the first year after budding and for four or five years afterwards it is possible by means of ladders or staging to investigate inflorescences at all stages and to carry out at will the delicate manipulations connected with artificial pollination.

An important principle laid down by Heusser was that the value of a mother tree for budding purposes could only be determined with certainty from the results of a tapping test of the budded progeny. Certain mother trees owed their high-yielding character to incipient disease or to favourable environmental conditions and were unable to transmit it to their descendants. This could only be elucidated by a tapping test.

Finally, Heusser laid down what he considered to be the soundest lines to follow in laying out plantings of buddings on a large scale. He recommended budding only from mother trees which had already been tested out for yield and found to be superior. He further recommended intermixing of the progeny of various mother trees, and that the planting should be carried out in rows between which seedlings grown from selected seed could be alternated. This procedure would later enable both the poor yielders among the seedlings and also the unpromising buddings to be thinned out without unduly interfering with the ultimate high-yielding stand.

This report of Heusser has been dealt with somewhat fully but as several others have emanated from him at intervals since 1924 it is of some importance to be able to judge how far the later results have confirmed earlier experiences and borne out earlier expectations.

(*d*) *Cramer's Work at the Buitenzorg Cultuurtuin.*

The year 1924 saw the publication of Cramer's historical lecture on the production of the budded trees in the Economic Gardens (Cultuurtuin) at Buitenzorg.(16)

Cramer's work differed in one respect from that of Heusser in that the buddings were carried out in 1916-18 but had to be left from April, 1919 until April, 1923 on account of Cramer's absence. Consequently, on his return, a good deal of time and labour had to be spent in tracking down planting mistakes.

Cramer also had very few trees at his disposal. The greatest number in any one clone was 18 and the results have often been criticized on account of this. In this connection Cramer's own introductory remarks in anticipation of such criticisms are of considerable importance. So far as the writer is aware they constitute the first public claim by a scientific worker of authority to a competency to draw conclusions of practical importance from an intensive study of a limited amount of material where usually a statistical examination of larger numbers has been regarded as essential.

Generally speaking, the trees of the Cultuurtuin showed the same characteristics as those of the A.V.R.O.S. station as far as rate and uniformity of growth, appearance, and cylindrical shape of stem are concerned.

Trees were taken into tapping when the girth at 1 metre was 50 cm. (19½ins.). Tapping was by a left cut over half the circumference at 1 metre, about 7 ins. of bark being used over the year. Where a comparison was possible buddings were found to give much more uniform yields than seedlings, but a lowering of the yield of the buddings as the cut approached the union was not clearly proved; in fact an actual reversal of this effect was found in some clones.

Cramer thought he was able to demonstrate an influence of the scion or budding upon the stock, for a fast growing scion was generally associated with a maximum circumference of stock, while, by tapping the stock, he showed that seedlings yielded more when budded with superior scions than they could yield at the same height if unbudded.

The chief of the clones investigated by Cramer were the Cultuurtuin Nos. 88, 3, and 9. It is not simple to gain an idea of their yields as so very few trees of each were available. From Cramer's Table XI, however, the mean daily yield of clone 88 may be calculated as 12 grms. of dry rubber if only those trees are included which were subjected to straightforward tapping. This figure corresponds to a yield of 456 lb. per acre. Only a single tree of each of the other clones is available for a similar calculation which shows the yield of No. 3 to be 415 lb. per acre and that of No. 9 to be 447 lb.

It is very interesting to compare the recommendations of Cramer with those of Heusser. The latter had felt justified in recommending a planting programme in which interplanted seedlings provided the necessary insurance against an unforeseen failure of the budded trees. The yields of the Cultuurtuin clones were greater than those of the A.V.R.O.S. but the numbers were much smaller, so that Cramer recommended planters to made an immediate start on a small scale with a field of buddings in order to gain experience. To assist this object Cramer offered budwood from the best of the trees in the Cultuurtuin, which had already by this date supplied 881 metres of budwood and 623 plants, presumably budded stumps. Cramer recognized that experience with budded Hevea trees was short, that the number of buddings was small and that future work might easily modify opinions already formed, but in spite of this, he felt sufficiently confident to recommend the further investigation of the possibilities of the budding method and the advisability of an immediate start.

One useful feature emerged from Cramer's preliminary work, namely, that all the buddings of a clone became ready for tapping within six months of one another.

(*e*) *The Work of the Anglo-Dutch Plantations of Java.*

Experimental work on the properties of this undertaking—the Pamanoekan en Tjiassemlanden—was started on the Wangoenredja Estate under its now well-known manager van der Hoop. The amount of experimental work on budding, seed selection, breeding and yield analysis, carried out under van der Hoop is so enormous that it can only be appreciated by seeing the results on the spot.

The first steps in budding were taken from the point of view of seed selection, the material being chosen from a planting consisting partly of trees planted in 1910-11 from Malayan seed and partly from others planted in 1905 from seed of "third generation import from Brazil."(17)

The trees, originally planted at about 110 to the acre, had, by strong selective thinning, been reduced to about 63 per acre.

Details of the tapping procedure are insufficient to allow one to see how the average daily yield figure was determined, but for 1923 it was evidently the mean of six alternate daily tappings.

In all, 24 mother trees were selected, nine from the 1905 planting and the remainder from that of 1910. The highest yield corresponded to the enormous figure of 269 grms. (9½ oz.) of dry rubber per tapping and the lowest to 76.5 grms. per tapping Both were from the 1910 planting of Malayan seed.

Buddings from all 24 mother trees were planted in April, 1923, in the Tjikadoe seed garden, 3½ kilometres from the nearest rubber, and as it was not intended to tap the buddings these were made at a height of about 4 ft. from the bottom of the stock. Six months after budding some of the trees came into bloom and the flowers were enclosed in muslin cages in order to prevent cross-pollination.

Seed from this Tjikadoe seed garden has already been offered for sale, both in the daily and technical press, for 1927-28 and subsequent planting seasons.

This is not an isolated example of the willingness of Dutch planters to co-operate with their research workers in trying out the new methods; in fact, the names of certain Dutch planters are as well known in the literature of Hevea budding as those of the research workers themselves. In March, 1924, Heusser(18) at a conference of the members of the A.V.R.O.S. at Medan, in the course of a long discourse on the selection of Hevea, made interesting mention of such assistance. The Experiment Station had already been able to distribute budwood to estates over the whole East Coast district but this was only because seeds and budwood had been previously received for testing from many estates both in Sumatra and Java.

III.—The Establishment of the Method.

The preliminary experimental work referred to above was sufficient to convince progressive planting companies that here was a method which was sufficiently promising of economic gain to make its full investigation imperative. The definite establishment of the method was, however, due to a vigorous experimental attack, both on the plantation and experiment station, which was developed in Sumatra and Java from 1923 onwards. It is the purpose of this section, therefore, to summarise the results of this attack.

(a) *The Pasir Waringin Clones.*

Although the preliminary tapping of the Pasir Waringin clones had given results which were by many regarded as disappointing, the results for the best plots were regarded by those concerned as being sufficiently promising to justify an attempt to identify the best of the clones. Mixing had certainly occurred during planting and it should be remembered that at this time, the problem of clone identification had received no attention whatever. In 1926 the investigation of seed character, branching habit and leaf form made it possible to identify accurately 25 clones comprising 1,481 trees. Systematic tapping tests were therefore continued, the system employed being alternate daily on a cut of one-third.

During the years 1927 and 1928 the average yield per tree per day for the 25 clones varied from 11.8 to 34.1 grms. of dry rubber so that in the latter year the ten highest yielding clones were selected for further test and the remainder eliminated. These ten clones now comprise 398 trees, the largest clone having 83 trees and smallest 10.

Thus, after tests carried out on satisfactory numbers, the average yield of the best clone was shown to be 12 lb. per tree per annum, allowing 160 tapping days, which, with 90 trees to the acre, gives a yield per acre of over 1,000 lb. at the age of ten years.

(*b*) *The Bodjong Datar Clones.*

The first published account of the performance of the Bodjong Datar buddings appeared in July, 1927.[31] The same difficulties due to mixing during planting as had occurred on Pasir Waringin were again encountered but identification investigations were begun in 1925 and pursued vigorously. Early in 1925, therefore, it was possible to distinguish no

TABLE V.

Clone.		No. of Trees.	Mean Yield Dry Rubber.	
Proefstation Number.	Estate Number.		Grms. per tree per tapping.	Lb. per tree per year.
PR 157	BD 5	8	49.6	17.5
PR 158	BD 10	93	44.7	15.7
PR 159	BD 2	29	41.2	14.5
PR 144	PE 147	22	32.1	11.3
PR 143	PE 172.1	48	28.7	10.1
PR 142	KH 54.1	23	23.7	8.3
PR 172	KH 54.11	10	19.6	6.9

less than twenty clones varying in number of trees from three to 120. These were brought into tapping in 1925 and the tests were continued in the two following years. The performance of the seven best clones is shown in Table V for the period June, 1926 to May, 1927, i.e., for the ninth year. The tapping was carried out as usual on a third cut alternate daily.

In July, 1927 therefore the three best clones were listed by the Proefstation voor Rubber, the staff of which had supervised the tests, as provisionally proved, that is, as suitable for planting on a commercial scale. Budwood and stumps were offered for sale the same year, deliveries being promised at the end of 1927 and the beginning of 1928. Since then the sales of both have been on an enormous scale, nearly 12 miles of budwood being delivered in 1928 and about 28,000 budded stumps.

Bodjong Datar Estate is an impressive illustration of the economic advantages to be derived from the application of scientific methods to the rubber plantation in co-operation with scientific assistance. Concentrating on the best clones it has cleared the ground formerly occupied by the inferior ones and planted these up chiefly with BD 5 and BD 10. Its budwood nurseries are on a magnificent scale and the organization for its exploitation appropriate while equally impressive are the estate's own new clearings, cleaned as clear as arable fields and planted up with acre after acre of BD 5 and BD 10.

(*c*) *The Avros Clones,* 1924-28.

In 1924, Heusser began again to tap clones 33, 36, 50, 52, and 80 which, as previously mentioned, were growing in isolated seed gardens on different estates.(19) Tapping was daily for alternate months but, as the number of tapping days per month varied from 15 to 28, the actual total for the period May, 1924 to March, 1925 was only about 150 tappings.

Tapping was on a half left cut at an angle of 30°. The first two to four tappings were continued on the panel of the first period, which started at 50 cm. above the union, after which a change over to the opposite side at a height of 1 metre was made.

From Heusser's figures a table very similar to Table I may be constructed. The figures in the final column give the ratio of the 1924 yield to that of the preceding year and are useful as indicating relative rates of increase.

Thus, in all the clones the increase was satisfactory but strikingly so in clones 33, 36, and 50.

Heusser made the interesting observation that all the buddings from one clone did not winter at the same time. Difference in wintering response is probably the most strongly marked physiological character of plantation rubber and Heusser's observation indicates clearly the possibility of stock influence which is able to modify the wintering response of a bud grafted upon it. It should however be noted that no influence of the stock upon the yield of the buddings could be determined.

TABLE VI.

No. of Clones.	Age.	Girth at 40 ins.	No. of trees.	Average annual yield	Yield 1924 / Yield 1923
52	5 yrs.	24 ins.	11	4.56 lb.	1.59
80	5 „	25 „	9	4.60 „	1.82
50	5 „	25½ „	10	7.07 „	2.81
33	5 „	20½ „	11	5.16 „	2.18
36	4 „	20 „	11	3.90 „	1.74

Fortunately on this occasion the budding yields could be compared directly with those of a field of seedlings from selected seed. These were of the same age as the buddings and were tapped on the same system. Clone 50 tapped at 86 cm. (34 ins.) gave three and a half times as much as the seedlings when tapped at 50 cm. (20 ins.).

The growth of the budded trees left nothing to be desired but the greatest step forward was due to the opportunity of inspecting panels of renewed bark, the oldest portions of which were two years old. Generally speaking the renewal seemed a little less vigorous than that of well-growing seedlings but this was not the case with clone 50, the renewed bark of which was quite as good as that of seedlings. Only clone 33 which was growing on clayey soil gave the impression of a rather slow bark renewal. In consequence Heusser thought it advisable that the period of tapping on the primary bark of budded trees ought at least to be about ten years.

The most important conclusion affecting estate practice was that the earlier advice to plant seedlings and buddings in alternate rows was likely to be invalid for future plantings which ought to consist only of buddings so long as the clones employed were as good as, or better than, those of the A.V.R.O.S. Heusser considered that in future only seeds from strictly selected mother trees deserved to be planted in conjunction with buddings from good clones, and, as the supply of such seed was likely to be very limited for a few years, it was better to plant buddings exclusively rather than carry out part of a planting with ordinary seedlings.

No doubt Heusser gained the confidence necessary to make this recommendation from being in a position to estimate the yield of a six-year old plantation of buddings at about 360 lb. per acre while he expected that at the age of ten years the production would be at least double this. The later performance of some of the A.V.R.O.S. clones has more than borne out this first estimate and augurs well for the fulfilment of the second.

An extremely interesting experiment was described by Heusser in December, 1926.[6] This had for its object the test tapping of three groups of buddings (clones 27, 35 and 49) and three groups of seedlings. Of the latter, one group was grown from the seed of a tree obtained by crossing flowers of clone 36 with pollen from a tree of clone 35. The second group was from selected illegitimate seed of tree 49. Both lots of seedlings were planted in the field in October, 1919. Group No. 3 was from what is commonly called "selected seed," viz., from a group of good seed trees. These were transplanted as stumps from the nursery in 1920 and consequently the root system was one year older than that of the seedlings of the two groups above, but the shoot was only six months older.

This raises a somewhat important point in the technique of comparative tests and one which has not yet received the attention it deserves. It is the general practice to conclude that a stump, when planted out at a given age, is approximately the same age as a budding which is pruned and planted out at the same time. The trees are not however exactly equivalent in several senses. In the first place the shoot of the budding receives its first stimulus to growth at the time the stock is ringed. To this extent it must have the advantage of the shoot of the stump, which receives its first growth stimulus from pruning at the same time as the shoot of the budding receives its second, i.e., when the stock is finally cut back.

In the present case, Heusser's assumption that the bark which was tapped had almost the same age on all trees may be taken as approximately correct.

Tapping was (daily?) by means of a 30° left cut over half the circumference at a height of 50 cms. (20 ins.). After one year the panel was changed and a new cut started at 1 metre (40 ins.).

The yield figures obtained during the first year showed that the rate of increase of yield was very much the same in all groups of buddings and seedlings. The performance of the seedlings of the cross was easily the best, while next in order followed the buddings of clones 35 and 49. The illegitimate seedlings from mother tree 49 came next, while the buddings from clone 27 were the worst. In all cases the average yields were greater than those ordinarily to be expected from four-year seedlings, while, with each group, the variability of yield was much greater in the seedlings than in the buddings.

These features are shown by the figures of Table VII.

Reference to Table I will show that the yield of clone 49 was two and a half times what it was a year previously.

After tapping for one year the panel was changed and a new half cut started at 1 metre (40 ins.). As a result a most interesting phenomenon was observed; the yields of the buddings continued to rise at approximately the same rate, while in the

TABLE VII.

Planting.	No. of Trees.	Age.	Average annual yield.	Daily yield grms. dry rubber.		
				Highest	Lowest	Mean
Seedlings from cross 35 × 36 ..	20	years. 4½-5½	lb. 3.95	21.3	6.6	11.2
Illegitimate seed from M. T. 49 ..	9	,,	2.60	19.2	2.2	7.4
"Selected" seed ..	10	5½-6½	2.32	13.4	2.0	6.6
Buddings—clone 27..	11	4½-5½	1.97	7.4	3.9	5.6
,, ,, 35..	26	,,	3.06	13.8	4.0	8.7
,, ,, 49..	35	,,	2.92	14.8	5.3	8.3

case of the seedlings there was an immediate sudden fall in the yield. Furthermore the recovery was so slow that in October, 1928, the yield had not yet reached the level of the previous March. On this account, during the first half of the second tapping year the buddings 35 and 49 were able to forge ahead of the seedlings of the cross 35 x 36, while the lowest yielding clone 27 was able to creep up from the bottom to fourth place.

For the next year, 1926, figures are only given for the months of July and September which are two of the best months of the year. In the latter month the cross 35 x 36 was still well ahead with a daily average of 29.2 grms. of dry rubber, clone 49 was second with 23.3 grms., while the trees from "selected" seed were by far the worst with 8.4 grms.

These figures only give the performance of these clones on the estate in question and Heusser himself considered that the value of the experiment was detracted from by the fact that some plots grew much better than others. This should be kept in mind constantly for it is necessary to realize that it is impossible to give the specific performance of a clone which shall be true for all sets of conditions. For example, in 1925-26 a test was carried out of four trees of clone 49 growing in the A.V.R.O.S. isolated seed gardens. The average yield of dry rubber per tapping was much higher in these trees than in those on Tinta Radja as the figures of Table VIII show.

TABLE VIII.

	MEAN YIELD PER TAPPING: DRY RUBBER.		
	June, 1925.	August, 1925.	October, 1925.
A.V.R.O.S. ..	17.0 grms.	21.0 grms.	25.3 grms.
Tinta Radja ..	13.7 „	16.5 „	18.8 „

These figures are quoted to correct a widely held opinion that a particular clone has an intrinsic yield, characteristic of itself, which it will give under any set of conditions. Thus, it has become the practice to speak of a clone as a "1,000 lb. per acre clone" and so on. Buddings are affected by soil and climatic conditions just as seedlings are and although the uniformity of high yield of proved buddings can be regarded as established, the average level of the yield is just as liable to be raised or depressed by soil conditions as in the case of seedlings.

So far as the Tinta Radja buddings are concerned it only remains to give the yields referred to above as being taken in July and September, 1926 (*see* Table IX). In these months the yield is always high and the mean yield may be taken as roughly 20% higher than the mean yield for the year.

For the further progress of clone 49 we need to consult the figures for four trees in one of the A.V.R.O.S. seed gardens which were tapped by Heusser in 1924-26. The individual mean yield showed an astonishing degree of uniformity from

TABLE IX.

Planting.	No. of trees.	Age years.	Average annual yield per tree.
Seedlings from cross 35 × 36.	26	6¾	9.43 lb. d. r.
Illegitimate seed from M. T. 49.	14	6¾	6.75 ,,
"Selected" seed	214	7¾	2.73 ,,
Buddings–clone 49.	103	6¾	7.74 ,,
,, ,, 35.	228	6¾	6.34 ,,
,, ,, 27.	112	6¾	4.96 ,,

tree to tree and the mean daily yields for all the trees for the two years in question are given in Table X.

Further news of the above six groups of trees was communicated by Heusser in January, 1928[22] when he gave the results of tapping from November

TABLE X.

Clone 49. Four trees; aged four and a half to six and a half years.

Year.	YIELD OF DRY RUBBER.	
	Mean daily yield.	Mean annual yield per tree.
April 1924—February 1925	11.5 grms.	4.04 lb.
April 1925—February 1926	23.9 ,,	9.41 ,,

1926 to September, 1927. These results are given in Table XI, column 2, of which contains the number of trees at the beginning and end of the experiment respectively. It will be seen that while the seedling trees from the crossing of clones 35 and 36 were still easily the best and those from "selected" seed still

TABLE XI.

Planting.	No. of trees.	Age years.	Average annual yield per tree.
Seedlings from cross 35 × 36	21–18	7	12.04 lb.
Illegitimate seed from M.T. 49	24–13	7	8.41 ,,
"Selected" seed	232–289	8	3.70 ,,
Buddings—clone 49 ..	111–108	7	8.76 ,,
,, ,, 35 ..	236–217	7	7.50 ,,
,, ,, 27 ..	106–100	7	6.65 ,,

the worst, the buddings continued to improve, the yield of clone 49 being three times what it was two years previously.

Into this experiment Heusser brought three other clones 28, 36, and 139, the first two being about equally good as No. 27 and the third slightly inferior.

Referring again to Table VI, the clones listed there were tapped again in 1925-26 by Heusser, that is, when the trees were six years old.[21] During the interval three trees of clone 33 had been treated for Brown Bast by the isolation method of Keuchenius, two of No. 36 had been broken by storms and one of clone 80 had been put out of tapping owing to an attack of Pink Disease. The results of the tapping test are summarised in Table XII.

Comparison with the figures of Table VI shows that all the clones had well maintained their rate of increase of yield and were giving yields greatly in excess of those given by seedlings of the same age.

TABLE XII.

No. of clone.	Age years.	Girth at 40 ins.	No. of trees.	Mean annual yield per tree.	Yield 1925 / Yield 1924
52	6	28.2 ins.	11	6.94 lb.	1.52
80	6	28.8 „	8	7.77 „	1.69
50	6	30.5 „	10	12.60 „	1.78
33	6	22.7 „	10	9.67 „	1.87
36	6	22.2 „	10	8.18 „	2.07

Later results given by these clones in Heusser's seed gardens were obtained during the period May, 1926 to September, 1927, and a summary of these is given in Table XIII.[22]

TABLE XIII.

No. of clone.	Age years.	Girth at 40 ins.	No. of trees	Mean annual yield per tree.	Yield 1926 / Yield 1925
52	6½–7⅓	30 ins.	11*	7.95 lb.	1.14
80	6½–7⅓	37.9 „	8†	9.22 „	1.18
50	6½–7⅓	34.2 „	10†	10.34 „	0.82
33	6½–7⅓	25.6 „	10*	8.45 „	0.87
36	6½–7⅓	25.2 „	10‡	9.18 „	1.12
49	6½–7⅓	27.7 „	4	11.39 „	—

‡ One tree—one year younger. * Two trees—one year younger.
† Three trees—one year younger.

Figures are also given by Heusser for the first half of the 1927 tapping year. These are summarised in Table XIV.

TABLE XIV.

No. of clone.	Age years.	No. of trees.	Mean anuual yield per tree.	Yield 1927. / Yield 1926.
52	7½–8	11†	5.92 lb.	0.74
80	7½–8	8	8.38 „	0.91
50	7½–8	10*	11.52 „	1.11
33	7½–8	10*	9.67 „	1.14
36	7½–8	10‡	9.07 „	1.09
49	7½–8	4	11.70 „	1.01

† One tree—one year younger. * Two trees—one year younger.
‡ Three trees—one year younger.

There is independent supporting evidence of the value of clone 80 in the results of tapping a number of clones on Boekit Maradja Estate, Sumatra.[20] The trees were three and three-quarter years old and as the experiment is referred to in some detail below only a bare mention of the performance of clone 80 will be made at this point.

The mean annual yield per tree was 3.15 lb. of dry rubber, corresponding to a yield per acre which was almost two and a half times that of a field of seedling trees of the same age.

The buddings on Boekit Maradja were carried out in October, 1922 upon an area of 457 acres which was divided into blocks. The clones employed were A.V.R.O.S. Nos. 80, 152, 71, 76, 163, and 174 from the Perdagnan isolation gardens.

At the same time a plot of seedlings from estate "highest yielders" was planted in a neighbouring area. In both cases the planting distance was 24 ft. by 24 ft.

A complication was however introduced by the fact that in both areas coffee was interplanted, being started in the budded area in 1920-21 and in the seedling area in 1922. In the latter case the coffee was retained throughout the experiment but in the budded area it was uprooted in 1925-26 and replaced by Calopogonium.

Opportunity may therefore be made at this point to emphasize once more how difficult it is to arrive at any precise numerical criterion of the performance of a single clone in more than one district or of more than one clone in the same district.

Considerations of space prohibit a description of the experimental conditions of each separate test although these are essential to a proper judgment. They have, moreover, never been the same in any two tests even when carried out on the same ground. Furthermore, in all cases the number of trees has been small while occasionally some of the original trees have been taken out of tapping during the course of the trial and new trees taken in. At times the trees of one clone have not all been of the same age (*see* Table VII), while differences of age have characterized clones which have been compared together (*see* Table VI). Again, a standard tapping height has not been employed in all tests whilst in some it has actually been changed while the test was proceeding (*see* Table VII) with the result that the buddings responded quite differently from the seedlings with which they were being compared. The planting distances have not always been the same and at times have even not been specified, while seldom has uniformity been shown in cultivation methods, type of cover-crop or method of collecting and measuring the product, i.e., as latex or biscuit. Lastly, tapping methods have generally varied, not only in respect of height of first cut but also in rate of bark consumption, size of task and constancy of tapping personnel.

Returning once more to the Boekit Maradja buddings[20] these were formed into groups of 200 trees, which were taken for tapping with no special favour but just as they occurred in the rows. The seedlings also formed a group of 200 but only the best of these were taken, e.g., those especially well developed growing on either side of a main road. This was done deliberately in order to counterbalance any disadvantage to the seedlings caused by the presence of the interplanted coffee.

Each group was subdivided into two series, "A" and "B." The trees, all of which were 40 cm. or more in girth at 1 metre from the ground, were tapped daily during alternate months. The trees of series "A" were tapped during the odd months and series "B" during the even months. Tapping was started by means of a left half cut at a height of 50 cm. and the results for the twelve months July, 1926 to June, 1927 are summarised in Table XV.

TABLE XV.

Planting.	Age.	No. of trees.	Mean girth at 40 ins.	Mean annual yield per tree.	Yield buddings / Yield seedlings.
Clone 80	3¾	200	23.2 ins.	3.31 lb.	2.49
„ 51	3¾	200	23.3 „	1.68 „	1.26
„ 152	3¾	200	22.0 „	4.55 „	3.42
„ 71	3¾	200	23.2 „	3.57 „	2.69
„ 76	3¾	200	21.5 „	2.40 „	1.80
„ 163	3¾	200	23.3 „	3.13 „	2.35
„ 174	3¾	200	22.5 „	2.33 „	1.77
Seedlings	3¾	200	25.0 „	1.33 „	1.00

In all cases the yield continued to increase during the first six months which shows the importance of all such tests being begun in the same season in order to exclude unknown effects due to such factors as wintering. Every clone was superior to the seedlings, 152, 71, 80, 163 especially so; the highest yield of all from 152 was equivalent to 490 lb. per acre, whereas the yield of the seedlings did not reach one-third of this.

Probably the most interesting figures are those for the thickness of the renewed bark, after six months, of the three clones 80, 152 and 71. This was 6 to 7 mm. which must be regarded as perfectly satisfactory.

Interesting details of the different clones were given. For example, No. 80 was more liable to Pink Disease (*Corticium salmonicolor*) in the rainy season than in the other clones: in clone 51 many of the scions grew more vigorously than their stocks, causing a reversal of the elephant foot phenomenon, an effect which has been previously recorded for plums grafted on peach stocks and prunes grafted on apricot.[23]

The A.V.R.O.S. clones which have come successfully through their testing periods are 33, 35, 49, 50, 71, 80, 152, 153, and 256. In certain circumstances 36 and 147 are also good but the data concerning the latter are scanty. This may appear a small number of survivors from the very large number tested but it must be remembered that, in order not to miss anything of value, it would be necessary in the early days to test every mother tree which showed signs of being a high-yielder and later, to weed out very many owing to their high yields having been traced to factors other than the inherent capacity of the trees for yield.

In May, 1927[24] the Director of the A.V.R.O.S. Experiment Station announced that the four-year old buddings from No. 36 had suffered considerably from wind damage owing to their tendency to form heavy secondary branches with crotch-shaped forks at the junctions with the main branches. The wood itself also appeared more brittle than that of other clones. Damage chiefly occurred in rapidly-growing trees on good soils; more slowly-growing trees on clay were not damaged, nor had the 22-year old mother tree shown any signs of weak forks or brittle wood. It seemed possible, therefore, that the trees were only liable to damage at a certain age but in view of the uncertainty it was deemed advisable, in spite of its high yield, to advise either that this clone should not be planted at all or planted on a limited scale only surrounded by trees of other clones.

Clone 52 was, at the same time, reported as objectionable on account of the tendency shown by some buddings to form excrescences on the tapping panel while No. 31 was also reported adversely upon on account of its slow growth.

Quite recently our knowledge of the A.V.R.O.S. clones has been considerably supplemented by a very complete review by Heusser[50] of tapping trials of no less than 47 clones. Of these some have been tapped only during the last two or three years but the majority have now been in tapping for the years 1923-28. It will be clear, therefore, that this review is of the utmost importance.

Most of the clones have already been considered above, but the review includes the latest performances of all.

The tests were carried out in the experimental areas already described, viz.:

(*a*) The A.V.R.O.S. isolated seed gardens. (Clones 33, 36, 49, 50, 52, 80, 139 and 142).

(*b*) The trial ground Tjinta Radja. (Clones 27, 28, 35, 36, 49, 139 and seedlings as described in[6]).

(*c*) The trial ground Boekit Maradja. (Clones 33, 49, 51, 53, 65, 71, 76, 80, 147, 152, 163, 174, 182 and seedlings as described in [20]).

(*d*) Temiang Rubber Estate. (The new and promising clone 256).

(*e*) The Soengei Pantjoer trial ground. (31 clones including 33, 49, 36, 183, 185, 186, 188, 207, 208, 214, and 222).

In the isolated seed garden No. 49 gave an average daily yield in 1928 of 34.5 grms. when tapped daily in alternate months over one-third of the circumference. This result was given by the four uniform trees planted out in 1919 (*see* Table I.). The rate of increase can be judged from the daily averages for the month of October in 1927 and 1928; these were 25 grms. and 47.8 grms. respectively.

During the same year nine trees of Av 50 gave an average yield of 31.1 grms. per tapping, the rate of increase being from 36.6 grms. in November, 1927 to 46.4 grms. in November, 1928. The performance of clone 50 was not so good as that of No. 49 and

Heusser was inclined to consider the vigorous fruiting of the former as partly responsible for this result. Taking all the figures into account, however, Av 49 appears much superior to Av 50 as the data in the following table show.

TABLE XVa.

Clone.	No. of trees.	Average Daily Yield: Grammes Dry Rubber.						Remarks.
		1923	1924	1925	1926	1927	1928	
Av 49	4	4.0	9.9	20.6	32.5	35.8	34.5	planted 1919
Av 49	100	—	6.2	14.5	21.3	25.6	30.7	„ „
Av 49	25	—	—	—	—	—	24.9	budded 1922
Av 50	9	6.1	14.7	30.3	34.0	29.5	31.1	planted 1919

The test tapping of the Tjinta Maradja buddings, seedlings and seedling crosses(6) showed that there was a distinct possibility of obtaining new and valuable clones from the latter. The results are summarised in the table below but due regard must be paid to the small number of seedlings tested and to the fact that the results obtained on Soengei Pantjoer were not so favourable.

TABLE XVb.

Planting.	No. of trees.	Average Daily Yields (grms. d.r.)	
		1927	1928
Buddings—Av 49 ..	100 +	25.6	30.7
„ Av 35 ..	225 +	21.7	26.5
„ Av 36 ..	40 – +	20.2	21.6
Seedlings—Selected	200 +	10.9	11.7
„ Illeg. 49 ..	10	25.2	40.4
„ Cross 36 × 35	19	35.7	45.8

As shown by the figures of the table below, the tapping tests on Boekit Maradja confirmed the promising character of clones 71, 152, and 163. The buddings were made in 1922 about the same time as the seeds were sown.[20]

TABLE XVc.

Planting.	No. of trees.	Average Daily Yield.	
		1927	1928
Clone 49	25	—	24.9 grms.
„ 71	100	12.9 grms.	21.9 „
„ 152	100	17.1 „	23.6 „
„ 163	50	12.7 „	20.8 „
Selected seed ..	200	6.3 „	9.1 „

Clone 256 was discovered during the test tapping of a budded area on Tanah Terbang Estate, the buddings being planted out in October, 1920. At first eight trees of the clone were identified but a further batch of twelve were discovered later.

The average daily yield during 1928 was 41.7 grms. per tree per tapping in the case of the above-mentioned eight trees. Tapping was daily in alternate months over half the circumference and a surprising feature is that the rate of increase during the year was insignificant, the daily average being the same in November, 1928 as it was in the previous January. The reason for this is not apparent but evidently it is a point to which attention should be directed.

In the opinion of Heusser the trees of clone 256 are almost ideal as far as growth, appearance, and bark character are concerned, so that the progress of these tests will be watched with particular interest.

The tapping of the new clones in the experimental ground at Soengei Pantjoer gave interesting results. The buddings were planted out in 1922 and 1923 and were brought into tapping in December, 1927. Ten trees of each clone were tested with the exception of No. 222 of which only two trees were available. The yield figures for 1928 are summarised below (Table XVd).

TABLE XVd.

Clone.	No. of trees.	Average daily Yield: Grammes Dry Rubber.		
		1st month.	Last month.	Av'ge for year.
188	10	8.1	21.3	11.7
207	10	8.0	21.9	12.2
208	10	7.6	21.9	11.1
209	10	10.6	26.0	14.2
214	16	9.2	25.0	15.2
222	16	6.4	24.9	15.3
183	5	20.2	30.4	24.0
185	4	39.9	43.9	35.1
186	6	19.9	34.9	20.5

Six clones, viz., 183, 185, 186, 209, 214, and 222, gave higher yields than any of the old clones at present in use, but Heusser recommended that further yield figures should be awaited before the clones were definitely evaluated.

According to Heusser, clone 185 stands out particularly by reason of its high production. It suffers, however, from the disadvantage of forming a grooved and crooked trunk.

The most important of Heusser's conclusions from the whole series of tests were the following:

(1) As regards both yield and period over which observations have been made, clones 49, 50, 71, 152, 163 are foremost in the list of A.V.R.O.S. clones.

(2) Clones 183, 185, 186, 209, and 214 are worthy of interest and further observations.

These latest results of Heusser support the opinion that superior clones will often be discovered in the future and that the search for such should not be relaxed. They also demonstrate the gradualness of yield improvement for while better clones are being subjected to prolonged test planting on a commercial scale must be restricted to those which have already passed this stage.

(*d*) *Further Work at the Buitenzorg Cultuurtuin.*

Experimental work was actively carried out at the Cultuurtuin, chiefly under Cramer's guidance, but reference to many of the experiments will be made elsewhere as their object was to throw light upon the physiology of budding rather than on its economic possibilities. Some clone selection work was however carried out, the best known to be discovered being Ct 88. This was produced by budding from Tree 88, a high-yielding daughter of Tree No. 3 which was one of the 11 survivors from a batch of trees raised from seed imported from Penang, Straits Settlements, in 1882. The remaining trees, being low yielders, had been cut out while the 11 survivors, at the age of 36 years, gave daily yields varying from 30 to 70 grms. of dry rubber. The yields of three of the Cultuurtuin clones are given in Table XVI.

Two other clones developed were Br I and Br II, which came from mother trees on Bogorredja Estate. Buddings made in 1922 when tapped in 1928 gave an average of 13 to 19 grms. of dry rubber per tree per day while in the same year buddings made four years earlier gave from 7 to 14 grms.

All these clones are of average merit and they have naturally been recently completely overshadowed by the higher yielding clones of Tjirandi,

TABLE XVI.

No. of Clone.	Annual yield per tree of buddings planted in 1918.		
	1926	1927	1928
Ct 88.	5.4 lb.	9.0 lb.	12.6 lb.
Ct 16.	7.2 ,,	9.7 ,,	11.6 ,,
Ct 3.	4.1 ,,	8.4 ,,	12.0 ,,

Bodjong Datar and the Avros; in fact, everything points to the gradual elimination of all clones which do not, at the age of eight years, yield at least an average of one ounce of dry rubber per tapping over the whole year.

(*e*) *Further Progress in Java.*

During the period 1924-28 a well-organized programme of work on the selection of superior planting material has been vigorously pursued by the research stations of Java. In this search all the Experiment Stations for rubber have taken part and there has been whole-hearted co-operation on the part of many estates. A feature of the work has been the periodical communication by Dr. de Vries, the Director of the Central Experiment Station for Rubber, of well-balanced judicial accounts of the progress made up to date. These cannot have failed to be of great service to the planting community.

In 1925, Schweizer[25] gave a preliminary account of the activities of the Besoeki Experiment Station, with regard to selection of mother trees and the testing of their offspring in East Java, and Arisz[26] described how on Oud-Djember Estate isolation gardens of buddings had been planted with a view to providing superior seed and also for the proving of 23 mother trees.

In September, 1926 de Vries delivered a lecture [27] which was a review of the position in Java at that time with respect both to buddings and selected seed. From this it transpired that the advice of the Java Experiment Stations was to plant both superior seedlings and buddings of tested and approved clones together, well mixed, with 160 to 200 trees to the acre. De Vries stated emphatically that whatever the distant future might bring buddings were undoubtedly the best planting material for the immediate future. Amongst many interesting items touched upon he mentioned the existence of a local advisory service for teaching the details of the technique. De Vries gave a very clear exposition of the planting policy he regarded as the best at that time. He advised strongly against the planting of unproved buddings on a large scale. Instead he advocated the budding of 20 or 30 trees from any exceptionally fine tree on the estate together with a few rows of clone Ct 88 as a standard of comparison. In this way the yields of the experimental clones could be expressed as percentages of the yield of the standard clone and made comparable with results elsewhere.

For estates which intend testing out their own high-yielders this advice is as good to-day as it was in 1926.

Another point which was brought forward by de Vries was that it was far better business to buy budwood of proved clones rather than selected seed. He calculated that in Java it cost 25 florin cents to produce a successful budding from imported Sumatra budwood. For this outlay a tree resulted which could be relied upon to give the yield of the proved clone. With illegitimate seed this certainty did not exist; the production capacity of the seedlings was unknown whilst the variability was much greater.[32]

At the same time Bally[28] was able to communicate somewhat similar progress in the province of the Malang Experiment Station. Here again estates shared in the work of planting buddings from Pasir Waringin, Bodjong Datar, and Sumatra. Other estates, e.g., Limburg, with the help of the staff of the Research Station, planted large areas of buddings from estate mother trees in 1922-23. This was supplemented by buddings from mother trees on other estates.

Planters were also advised by Bally to follow the example of Limburg estate and set up multiplication nurseries of buddings from the best Java and Sumatra clones.

In March, 1927, Schweizer added a general account of the progress made in Besoeki (E. Java), showing that reliance was being placed chiefly on A.V.R.O.S. clones with some of the Cultuurtuin clones for comparison.[29]

In April, 1927, de Vries continued the history of progress in Java.[30] He mentioned the existence of a scheme in which all the research stations were to co-operate for the purpose of supplying superior planting material to estates. Provisionally, however, estates were encouraged to import A.V.R.O.S. budwood and de Vries mentions 16 estates having imported 2 kilometres between them.

Testing gardens had already been planted up on several estates and an experiment on the high tapping of buddings started. Cuts started at 2½ to 4 metres (8 to 13 ft.) in height all gave yields which, lying between 45 to 70% of normal, promised to be economical to exploit when prices were good.

Recently, extensive and well-organized trial grounds have been laid down in different districts and at very different elevations where promising clones can be tested against one another and also against so-called "standard clones," e.g., Ct 88, Av 36 and Av 50. When available the results of these trials should be of tremendous importance to rubber growers.

(*f*) *The Work of the H.A.P.M. up to 1927.*

The very important work carried out on the estates of the H.A.P.M. in Deli, Sumatra, was described by Grantham in 1927.[5]

From the results of tapping records commenced in 1927 Grantham was able finally to classify the trees examined over 37,000 acres into the three classes of Table XVII.

In 1923 more intensive tapping tests were carried out on 250 of the very best trees and showed that yields greater than 30 lb. per year were given by 17 trees in 1924 and 21 in 1925. These were all ordinary plantation trees standing 80 to the acre and aged about 14 years.

TABLE XVII.

Class.	No. of trees.	Per cent of total number.	Av. yield per tree in 1921. lb. dry rubber.
I	1,292	.03%	14 lb.
II	31,487	.07%	10 ,,
III	198,411	4.5%	7 ,,

The H.A.P.M. buddings were in two series; an early one consisted in planting out 10 acres from nurseries in 1918 and, according to Grantham, these were the very first buddings to be brought into tapping, on May 2nd, 1922, a few days before those on Pasir Waringin.

Large scale operations were not begun until 1920 and 1921, mother trees from Class I being used for the purpose: the yields of 91 of these clones are summarised in Table XVIII.

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TABLE XVIII.

No. of clones.	Class.	Average Yield; Lb. Per Tree Per Year.			
		4th-5th year.	5th-6th year.	6th-7th year.	7th-8th year.
2	Good	5.7	7.4	9.6	8.6
16	”	4.7	8.5	11.0	11.4
33	”	3.9	6.7	11.2	10.6
10	Medium	2.2	3.8	6.5	7.8
1	”	3.2	5.7	7.6	7.4
12	Poor	1.2	2.2	3.1	3.6
17	”	1.2	2.1	3.3	4.2

Unfortunately the tapping system is not mentioned so that it is not possible to compare the performance of these trees with the foregoing. It is however possible to calculate the number of grms. of dry rubber per tapping which would have been yielded had the number of tapping days been 160, and these figures are given in Table XIX.

TABLE XIX.

No. of clones.	Class.	Average Yield, Grms. Per Tree Per Tapping.			
		4th-5th year.	5th-6th year.	6th-7th year.	7th-8th year.
2	Good	16.1	20.1	27.2	24.3
16	”	13.3	24.4	31.1	32.3
33	”	11.1	19.0	31.8	30.0
10	Medium	6.2	10.7	18.7	25.7
1	”	9.1	16.1	21.5	20.9
12	Poor	3.4	6.2	8.8	10.2
17	”	3.4	6.0	9.4	11.9

Although ordinary test tapping was not commenced until the trees were four and a half to five years old, Grantham introduced a method by which trees might be tapped at the age of two and a half to three years in order to decide whether the multiplication of budwood should be undertaken. By this method the trees were tapped to the wood on half the circumference, the best trees giving 3 to 4 grms. per tapping. At the age of three and a half years, by normal tapping, yields of 7 to 10 grms. were obtained and one year later 15 to 20 grms.

It will be noted that, gradually, a more definite idea is being obtained of the standard which should be reached by a good clone during the first four years of tapping.

Grantham's procedure in the field from 1923 onwards was to take a clone as soon as it was proved to be good and bud from it into nurseries. On planting out the buddings later, at least five clones were mixed in each area while, as an insurance against the failure of any one of these, the rows were interplanted with seedlings.

Although this is the latest published record of the H.A.P.M. work it is well known to many planters and scientific workers that a vigorous planting policy, in accordance with the results established by its scientific staff, has continued to be pursued by this undertaking and a considerable debt of gratitude is due to its directors for the many opportunities generously afforded for an inspection of this work. A similar debt is due to the directorate and staff of the A.V.R.O.S. Experiment Station in Medan.

(*g*) *Budding in Malaya,* 1921-28.

The first attempts at budding in Malaya were taken by private enterprise, chiefly by larger undertakings which had their own scientific advisers. In addition, however, a number of individual managers, either with experience or interest in the horticultural branch concerned, took steps to try out the method on the estates under their charge. These pioneer attempts date from 1921-22 and suffered from two disadvantages: on the one hand the mother trees were selected from reputation alone and not from the results of tapping tests, or else the work was insufficiently organized and records neglected. The reason for the latter was probably the impression that it was sufficient merely to bud from a high-yielding tree in order to obtain the high-yielding trees desired, but, further, there is no doubt that there was a total inability to appreciate the nature and value of a high-yielding clone.

One result of these activities is that odd, small areas of buddings are encountered in the most unexpected places, all generally dating from 1921-23. When the writer visited the State of Kelantan, for example, in 1928, the first field of rubber he encountered contained a fine stand of trees budded during these early days.

But so far as official research activities were concerned there was a definite blank period from 1921-25.

As against this, the scientific staff of the laboratory of the Rubber Growers' Association began in 1922 to give publicity to the method by means of demonstrations of the technique both at their laboratory on Petaling Estate and on outside estates. The first outside demonstrations to be placed on record was one on Kamuning Estate, Perak, in October, 1922.

The Pilmoor Budded Area—In 1923 a combined selection and budding programme was planned in the R.G.A. Laboratory; work was begun on Petaling, Pilmoor, and Sungei Way Estates and on the former, 21 trees were selected as mothers. Of these 18 were high-yielders, two were low-yielders for comparison and one was a Brown Bast subject. Buddings were made from these in nurseries on Sungei Way and the buddings planted out as stumps in a small clearing on Pilmoor Estate, September to December, 1924. The trees were brought into tapping in January, 1928 on the area being taken over by the Rubber Research Institute.

In January, 1928 the trees were therefore three to three and a half years old from the date of transplanting as stumps, and it was decided to tap all trees which had a girth of more than 15 ins. at 40 ins. from the union.(42) As the trees were so young it was thought inadvisable to tap them commercially but to substitute a conservative scheme which without injuring or retarding the buddings would be likely to give an indication of the yielding capacity of the trees. The scheme adopted therefore was to tap the trees alternate daily in alternate months on an 8 ins. cut at a height of 20 ins. from the union.

Fourteen clones were tapped but only four showed promise.

Some interesting incidental points were recorded. The order of clone yields was not that of the mother trees; the mother tree of the best clone was second in order of merit while the best mother tree produced the third best clone; the second best clone came from the fourth best mother tree while the mother tree which was fifteenth in order of merit produced the fourth best clone.

During the test period measurements were made of both virgin and renewed bark and in a very convincing paper Billington(48) showed that this was perfectly satisfactory.

The second year's results from the commercial tapping of these clones will be of considerable interest.

The Sungei Reko Clones—Budding in Malaya will always be associated with the name of Gough of

Kajang Estate. Gough commenced budding 70 acres of seedlings in the field in October, 1921 and these buddings were brought into tapping four years later; in December, 1925, yield tests of the two clones SR 1 and SR 9 were made by Spring.(33)

The trees were selected at random from two groups and in his first test Spring found that whereas in one group the clone SR 1 was identifiable, in another it had not yet been possible to separate the trees of SR 9 from those of SR 1.

Tests were also made at the same time of some control seedling trees—age not known—of approximately the same average girth as the buddings. The trees were tapped at 20 ins. from the ground with a half spiral cut on alternate days. In all the tests the number of trees ranged from 14 to 17 and the results are summarised in Table XX.

TABLE XX.

No. of Test	Grammes of Dry Rubber Per Tree.				
	1	2	3	4	5
Clone 1	17.3	17.5	17.2	15.6	14.1
Clones 1 and 9 ..	23.9	22.2	18.1	15.4	—
Control (seedlings)	6.5	6.4	5.7	4.7	—

The first three readings were taken in December, the highest yielding period of the year, and the remainder in January.

The figures of Table XXI are also of interest as showing the greater relative uniformity of buddings as compared with seedlings.

Further tests were made by Spring(34) the following August and September. Unfortunately

TABLE XXI.

	Grammes of Dry Rubber Per Tree.	
	Best tree	Worst tree
Clone 1	24.9	9.5
Control (seedlings) ..	12.6	2.3

the figures for clone 1 are not comparable with those of the previous tests as they are given in cc. of latex but the figures for clone 9 showed a great improvement, the average yield per tree varying from 28.4 to 32.5 grms. of dry rubber per tapping. The average for six tests was 29.5 grms. of dry rubber which, on the basis already adopted, corresponds to an annual yield of 1,100 lb. per acre. The trees were then less than five years old and the average girth at 17 ins. from the ground was 24.4 ins.

Up to the time of writing no account has been given of other early pioneer work carried out in Malaya which accounts for the astonishing lack of knowledge, even locally, of the enterprise of certain Malayan planting companies and of the magnitude of the efforts made in 1921-23.

During 1927-28 thousands of acres of mixed buddings and seedlings have been planted, or are in course of being planted, chiefly in Kedah, Johore, and Negri Sembilan. In most cases Sumatran budwood has been used but Gough's clones and those of Prang Besar have served as the origin of a certain quantity.

All this work is too recent for a complete view of it to be sketched or a full description given. It is otherwise with the earlier work, and in order to illustrate the scope of this, a brief account will be given of the two operations which have impressed the author by reason of their magnitude and importance. These are the budded areas on Prang Besar Estate, Kajang, Selangor and on Sungei Tawar Estate, Kedah, of Gula-Kalumpong Rubber Estates, Ltd. In both cases the author is indebted to the respective companies for generous permission to make use of their results. In the case of Prang Besar Estate the manager, Mr. R. O. Jenkins, has not only furnished the necessary data but also given valuable assistance in many discussions on budding, while in the case of Sungei Tawar, Mr. J. W. Kennedy, the General Manager of Gula-Kalumpong, has kindly furnished details of the planting operation and given facilities for inspecting the trees.

The Prang Besar Clones—These owe their origin to Gough by whose advice they were planted. The buddings were made from a large number of high yielding trees on neighbouring estates so that altogether 618 clones are recorded as now present on the estate. Of these a first group of 180 clones was brought into commercial tapping in February, 1928 although preliminary test tappings had been carried out in July and August, 1926 and in June, 1927. A second group of 211 clones underwent a preliminary volume test in May, 1928, regular test tapping being commenced in October, 1928. The system of tapping was alternate daily on a half left spiral cut, bark consumption being between 10 ins. and 11 ins. for the year. The tapping tests have been carried out by the estate manager, Mr. R. O. Jenkins and his scientific assistant, Dr. R. J. Chittenden.

For recording purposes ten trees of each clone were selected, the selection being conditioned not by any character of these trees but by their proximity to one another and to other trees under test which formed part of the task of one tapper. Tapping errors due to the individuality of the tapper were excluded by interchange of tasks and reversal of the order of tapping at the end of each month.

Every effort was made to carry out the tests under the conditions of commercial tapping; thus the records include figures obtained by late tapping after rain and so on.

In order to support the selection of ten trees as a unit 100 trees of clone 186 were tapped during September and October, 1928 and the figures so obtained were compared with those given by the ten trees forming the test unit of the same clone. These figures are given in Table XXII.

TABLE XXII.

Clone 186	Average Yield per tree per tapping in grammes of Dry Rubber.	
	September, 1928.	October, 1928.
10 trees	36.8	39.3
100 „	35.7	36.9

As the average for the ten trees for the whole of the year was 34.8 grms., the selection appears amply justified.

The results for the eight best clones are given in Table XXIII. In addition it should be stated that the figures for bark thickness, girth increase, thickness of renewed bark and rate of renewal were perfectly satisfactory. The two clones lowest on the list are omitted from the table merely from motives of economy of space. These two, PB 49 and PB 155, gave over the year average yields per tree per tapping of 30.5 and 28.5 grms. respectively.

TABLE XXIII.

Average Yield: grammes Dry Rubber per tree per tapping.
(February, 1928 to January, 1929).

Clone	23	25	186	123	SR 9	24	180	5
February	34.6	38.4	25.1	28.7	23.1	26.3	—	—
March	22.6	26.5	21.4	17.9	20.3	23.5	—	—
April	28.5	26.7	28.5	17.1	16.9	24.5	32.6	28.2
May	31.6	30.4	33.9	26.9	23.7	20.6	27.0	25.7
June	38.4	35.5	30.3	33.2	27.0	29.8	30.3	32.2
July	44.8	40.6	38.1	34.9	31.6	29.6	30.3	33.2
August	47.3	38.5	34.0	36.2	25.4	30.8	37.2	30.5
September	43.6	38.8	36.8	31.5	35.4	38.9	31.3	29.4
October	42.7	32.7	39.3	26.1	38.2	38.2	39.3	36.0
November	43.6	39.1	42.6	32.8	53.6	40.8	43.5	34.6
December	48.0	39.1	40.5	45.5	41.5	42.5	39.6	38.3
January	45.6	45.1	46.9	54.6	—	49.4	42.7	39.6
Average for year	39.3	36.0	34.8	32.3	30.6*	32.8	35.4†	32.8†

*11 months' tapping. †10 months' tapping.

TABLE XXIV.

Clone.	Annual Yield per tree per tapping.	Date of planting.	Annual yield per tree (160 tappings).
PB 23	39.3 grms.	April, 1922	13.83 lb.
PB 25	36.0 „	„ „	12.67 „
PB 186	34.8 „	„ „	12.25 „
PB 123	32.3 „	June, 1923	11.37 „
SR 9	30.6 „ (11 mths.)	Oct., 1921	10.77 „
PB 24	32.8 „	Dec., 1922	11.54 „
PB 180	35.4 „ (10 mths.)	April, 1922	12.46 „
PB 5	32.8 „	„ „	11.54 „

In all cases the yield figures show a steady increase throughout the year. In comparing the clones due allowance should be made for differences of age.

Jenkins and Chittenden also made observations of the growth and characters of the clones which are extremely useful. They noted, for example, the incidence of diseases on the root and branch systems, the character of the bark and quality of renewal and the liability of the trees to wind damage. Up to the present time however no evidence is available to show that the development of disease in a clone is necessarily connected with budding. Naturally, a tree with a fastigiate branching habit will be predisposed to attack by branch diseases merely through mechanical causes, but Brown Bast and root diseases are in another category and there is no reason yet to suppose that certain clones are especially predisposed to attack by them.

The following are notes on individual clones.

Clone 23—No trees were attacked by Brown Bast or suffered wind damage. The trees were free from branch diseases but one was lost through root disease. The bark was soft, easily tapped and renewal was good. Growth was satisfactory, producing an excellent crown but the trees were not early maturing.

Clone 25—2.4% of the trees became attacked by Brown Bast but none has been observed since August, 1928. Three trees were lost by disease, 11 had to be treated for Pink Disease. The bark was thick with excellent renewal and the clone was early maturing.

Clone 186—This clone was formerly called 25A before being finally identified by seed. Two trees suffered from Brown Bast, one was lost through wind, one through root disease, and five were treated for Pink Disease. There were 300 trees in the clone. The bark was thick and not too easy to tap but its renewal was good.

Clone 24—The percentage of trees attacked by Brown Bast was 3%. Two trees were lost through root disease but there was neither Pink Disease nor wind damage. Growth was good, the trees were early maturing while the bark was thick and renewal good.

Clone 123—There was no loss due to wind damage nor any sign of root or branch disease. The character of the bark was good but the trees possess an open form of branching which produces little crown. They are, however, early in maturing while from a tapping point of view they possess two good characteristics. The latex stops flowing about two and a half hours and the dry rubber content is high (42-44%). Moreover the clone is early maturing.

The other clones have no unsatisfactory features and may therefore be judged solely on their yields.

Strict comparisons are perhaps not yet possible but it is interesting to compare the yield figures given by the Prang Besar clones with those of the Avros clones tabled in Chapter I. The former are well up in the same class as the latter and are rather better than the Cultuurtuin clones of Java, but as the best Java clones, e.g., those of Bodjong Datar, are older and have been in tapping for three to five years longer it is not possible to carry the comparison further. Again, most of the Java tests have been carried out on a third cut which makes comparison more difficult still.

What is of greater significance to planters is that the Prang Besar clones were budded as stated from ordinary estate high-yielders. This lends support to the writer's opinion that the prospect of discovering other good Malayan clones is quite favourable.

The Sungei Tawar Budded Areas—Gula-Kalumpong Rubber Estates first attempted budding operations on their Gula Estate in Perak where, in 1921, 40 acres of three-year old trees were successfully budded.

Already in 1918 yield tests had been started on the Gula-Kalumpong Estate. The primary object of these tests was selective thinning-out so every tree of the 4,000 acres on these estates was brought into test. Consequently, when it was desired to commence budding, tests were available of the yielding capacity of thousands of trees over a period of three years. The material for budding the Sungei Tawar clearings was taken from the highest yielding of these mother trees, upwards of 800 being pressed into service. Budding was carried out in 1921-23 on an extensive scale in the Gula nurseries, and by the end of 1922, on Sungei Tawar, an area of 500 acres with an average of 140 trees to the acre had been planted wholly with buddings. The buddings made in 1921 were planted out in 1922 as stumps but those made in 1922 were planted out just as the buds had burst.

In 1923 a second area of 360 acres was planted with alternate rows of buddings and seedlings from "selected illegitimate seed." About 100 acres were budded in the field and the remainder planted out with buddings from the nurseries on the Gula Estate.

In 1924 a further area of 440 acres was planted with alternate rows of buddings and seedlings, the majority of the buddings being made in nurseries on Sungei Tawar and planted out as the buds burst.

The distance from Gula to Sungei Tawar is 75 miles. The transport of the stumped buddings presented no difficulty for these were simply made up in bundles with a covering of sacking and transported by motor lorry. It was otherwise, however, with the buddings which were transported at the stage when the buds had just burst.

The method finally adopted was the following: After the buds had taken, the stock was cut back to a height of 18 ins. from the ground. When the buds had burst the plants were lifted and packed in specially made boxes of approximately the same length inside as the pruned plants. A layer of plants was placed on the bottom of the box with roots and stems alternating. These were held tightly in place by fitting a batten of wood tightly at each end and fixing these by nailing them from the outside. Further layers were dealt with similarly until the box was full.

The boxes were transported by motor lorry and on arrival at Sungei Tawar the loss was found to be practically nil.

Test tapping of the budded areas has recently begun and for many reasons the results should be highly instructive; at present the tapping figures show a result which was to be expected, namely, that clones of very different character are present varying from very high-yielders downwards. The clones are very mixed and planted to no definite plan but, taking all trees together, areas of several acres have given yields at the rate of 600 lb. per acre reckoning 160 tapping days and 80 trees to the acre.

Some of the individual trees are much better than this, having given yields corresponding to about double the above figure, and there is little doubt that some of these will come well up to the standard of the best clones previously mentioned.

Further Progress In Malaya—Recently budwood has been offered for sale by another undertaking—Rubana—one of the Lower Perak estates of the Penang Rubber Estates, Ltd. This is supplied from the best of a number of clones in the extensive budded areas on this estate. The buddings date from 1921 and the tests show that the best clones are about equal to those of Prang Besar. The best clone gave in its eighth year an average yield of 143 lb. per tree.

It is a task of some difficulty to give an idea of the acreage under buddings in Malaya but this is considerable and increasing steadily. Generally speaking, the commonest form of activity has been the planting up of new clearings with buddings and seedlings alternating, but a few estates have budded on a small scale from estate mother trees. As a rule however budwood from either Avros, Prang Besar, or Sungei Reko clones has been employed. The present year has seen the first introductions of the Tjirandi and Bodjong Datar clones and there is every prospect of increasing quantities being imported next season. From personal knowledge the writer estimates that over 120 Malayan estates now have budded areas but the acreage varies greatly in individual cases. At one end of the scale are those estates which have put down 10 to 20 acres as a trial, while at the other are estates of some of the more important organizations which have planted between one and five thousand acres.

(*h*) *Progress in Ceylon*, 1922-28.

Budding has failed to gain any appreciable footing in Ceylon but during the past three or four years there has been a considerable increase of interest in the method.

In 1922 a Silver Cup was offered by the Ceylon Rubber Research Scheme for competition among planters interested in budding. No record has been found of the number of competitors but the cup was won by Mr. C. E. A. Dias, a well-known Sinhalese planter in the Kalutara District, who in 1923 produced 4,600 buddings for inspection. Together with Mr. H. Roy Bertrand, another Kalutara planter, Mr. Dias has played a very great part in introducing the method into Ceylon, his first step being to send his Superintendent to Java to study the technique which he at once applied very successfully on his own estate. At the same time the Rubber Research Scheme sent a member of its subordinate staff also to Java, and on his return commenced budding demonstrations at Peradeniya.

In 1926, Messrs. Bertrand and Dias visited Java and Sumatra to ascertain the true position of budded rubber and seed selection. They returned convinced of the necessity for a more progressive attitude in relation to budding and began a vigorous propaganda for a trial of the method by estates both in the Press and in planting circles.[40] In the same year the Rubber Research Scheme commenced the opening of a small experimental ground of 50 acres for work in budding, and visits were made to a few estates for the purpose of advising on the selection of mother trees. In the following year an extensive budding programme was initiated at the Peradeniya Experiment Station which included the introduction of 19 stumps budded from Java material. From the low percentage of successes obtained (less than 30% as a rule) and from the meteorological records the impression is obtained that climatic conditions are on the unfavourable side at the smaller station.

From the work at Peradeniya, Holland[35] has recorded the successful budding of nearly 600 nursery plants between August 1st and October 7th, 1927, and the planting out in November of the same year of 400 stumps of which 52 stocks died. There was no instance of the bud dying and the stock surviving.

A progress report on budding was communicated to a meeting of the Estates Products Committee of the Ceylon Board of Agriculture on July 10th, 1928. From this it appeared that at the end of May, 1928, the number of budded plants on experiment stations of the Department of Agriculture and Rubber Research Scheme was 850. It was reported that losses had been considerable in 1927-28 and not all the above were expected to survive. On the new experiment station of the Rubber Research Scheme, already referred to, a further 277 budded plants were growing at the end of May and budwood nurseries had been established at this and two other experiment stations.

In June, 1928 a Government grant for budding proposals was obtained and this was allotted to four experiment stations by the Department of Agriculture. About the same time Mr. C. E. A. Dias as a member of the Estates Products Committee recommenced a vigorous advocacy of an accelerated budding programme.

In November of the same year there was considerable progress to report, for 51 mother trees were listed as having been budded from into nurseries. So far as one can gather from the list, the majority were of local origin but budwood from Java, Sumatra, and Malayan clones was also used. In these cases poor success was obtained in comparison with the local wood and it would have been interesting to have had fuller data on the different consignments, especially as the number of buds actually put on was very small. For example, from two Malayan clones, only three and eight buds respectively were obtained while the numbers for three Bodjong Datar clones were only slightly better. Strangely enough, the success with a consignment of Prang Besar budwood from Malaya and with a second one from Sumatra was decidedly better so that it appears as though methods of packing and duration of transport were not the only factors involved.

Concurrently, preparations were being made at the Peradeniya Experiment Station for establishing a trial area for the testing of mother trees.

One of the main features of interest of this rapidly developed work is the demonstration of the ease and speed with which such testing work can be instituted provided that the number of buddings from each mother tree is not too great. The limit to the number of trees it is desirable to test is then only set by the limits of the trial ground. It is obvious that, for some years, the exploration of the plantations of a country for suitable mother trees will form the main side of activity of its research stations. Consequently, details of experiences in this particular field are very valuable and the progress of these trials will be watched with interest.

The above summarises the work of the Department of Agriculture. Turning now to the extra-Departmental Rubber Research Scheme an account of its work is given in the Seventh Report dated April, 1929.[43] A small experimental area of 63 acres is available and this has been opened up roughly in two halves during 1926 and 1927. The objects of the testing work to be carried out here are not given but apparently consist of the trying out both of local and introduced clones.

From figures given in the report it is apparent that the standard of success had been raised to a satisfactory level for a census had shown that final successes of 54.1% and 100% had been obtained in the field and nursery respectively.

Buddings had been made in nurseries from 50 local mother trees and, in addition, several from Malayan clones had been successfully established.

(*j*) *Recent Progress in the Dutch East Indies.*

In view of its great scientific interest and economic importance it has been considered advantageous to discuss in a separate section the more recent advances made in Java and Sumatra. It will be agreed that after upwards of ten years of scientific investigation it becomes of some importance to be able to judge the extent to which the budding method has made an impression on planting policy.

Trustworthy figures with regard to planting questions are notoriously difficult to obtain as machinery for their collection does not usually exist. It has already been shown that the number of estates in Malaya which have budded areas can be estimated fairly closely but, so far as the writer has been able to discover, no such estimate has been made for the rubber plantations of Java. The position in the Sumatra East Coast area is clearer owing to the work of the A.V.R.O.S. Experiment Station which was furnished with the necessary figures by the estates composing the A.V.R.O.S. group. As yet figures are only available for the years 1920-27 but they constitute one of the most illuminating collections of planting data ever furnished to the rubber growing industry. The figures refer to new planting extensions only and account not only for the total area planted but for the acreages planted respectively with—

(1) Buddings only.

(2) Buddings and seedlings mixed.

(3) Selected seeds.

(4) Unselected seeds.

The total extensions in 1920 were just over 34,500 acres: during the slump years 1921-23 there was a fall to between 1,000 and 1,300 acres annually but from 1923 the rate of extension increased rapidly and regularly to 40,000 acres in 1927. From 1920-23 the total area planted with buddings alone was small, that is, between 1,000 and 2,500 acres. Even in the two following years the rate of progress showed no increase but in the next two years we find the acreage increasing until in 1927 the area under buddings alone formed one-quarter of the total extensions. In the case of mixed plantings of buddings and seedlings we find a similar state of things between 1920 and 1923 for in 1922 and 1923 only about 2,500 acres per annum were so planted, forming nevertheless nearly a quarter of the restricted extension acreage. From 1923 the rate began to increase regularly and rapidly until in 1927 over half the area of extension was under mixed buddings and seedlings. Adding the proportion under buddings alone we find that about 77% of the area was planted with budded stock.

But the interest does not cease here for most of the balance was planted up with selected seed, a mere 150 acres out of a total of over 40,000 acres being planted with ordinary estate seed. Interpreted generally the figures show that practically the whole of East Sumatra's new planting extensions are stocked with high-yielding material.

The explanation is not far to seek. This result has been achieved by whole hearted co-operation between the estates and research institutes of Sumatra. In 1923 the results of work of the H.A.P.M. and A.V.R.O.S. research staffs were beginning to be known and appreciated and the rise in the planting of mixed buddings and seedlings followed. By 1923 more experience of and confidence in the method had been obtained and the percentage planted with buddings alone began also to increase. Finally, by 1926, selected seed was being produced from budded seed gardens with the result that the use of ordinary estate seed practically ceased.

The activities of the research station of the A.V.R.O.S. have continued unremittingly. Not only have the best clones of the original ones described by Heusser been sorted out but newer and more promising clones have been investigated. As a result the A.V.R.O.S. members are now advised to plant for preference clones 49, 50, 71, 152, 163, and 256 as their best selections. In case of shortage of any one of these the next in order to be recommended are 33, 35, and 80, with 36 in reserve, as it were, for planting in situations where growth may be expected to be slow.

New clones to be distributed are 150, 183, 185, 209, and 214, and as only limited quantities of these are yet available members are advised to set up multiplication nurseries of them. So far as the improvement of planting material is concerned therefore, Sumatra seems likely to occupy an advantageous position for many years to come.

Figures such as the above are not available for Java which, unlike the East Coast of Sumatra, does not consist of a compact planting district with a central research station and a consequent simple organization. As against this, however, records of recent research work are both full and up-to-date. This work has been carried out not only in the different experiment stations but also in conjunction with estates possessing promising material.

On the trial grounds the work consists chiefly of clone testing for which a standard plan has been adopted. The buddings are planted about 20 ft. by 16 ft. apart in rows running north and south. Five trees of each clone are planted successively, the clones following one another, and this procedure is repeated three to five times so that every clone is scattered in different parts of the area. Included in the clones under test are three "standard clones" Av 36, Av 49, and Ct 88, while a border row of buddings from another clone is planted round the whole area. By this method it is hoped to exclude irregularities due to soil, border effect and tapping. Further, so many figures are available for the three "standard clones" that ultimately it should be possible to grade the remainder so far as their suitability for planting in Java is concerned. Trial areas of this kind are so valuable that, no doubt, their establishment will become a matter of routine in all rubber-producing countries, and controlled by their respective research organizations, they should enable judgments of some permanence to be made on clone values. Owing to differences of climate, soil and tapping systems it is not possible to do this at the present time.

In the early days of budding an interesting experiment was carried out on Pondok Gedeh Estate where buddings were made in 1920 from three mother trees and planted in a field which was situated 1,600 ft. above sea level. It was thought that if buddings were a success at this height it would give greater confidence for employing them at lower levels. The degree of success was great enough to permit of a decision being made to place one of the clone trial grounds here. Furthermore, buddings have also been planted at a height of over 2,200 ft.

Another line of activity has been the testing, under rigid conditions, of superior clones on certain estates. This work has consisted not only of test tapping but also of the study of the vegetative characters and seed of the trees in order to provide a trustworthy means of identification. As a consequence of the publication of the figures so obtained the attention of the whole planting industry has been drawn to the Tjirandi and Bodjong Datar clones. Figures have already been given for the yields of the latter during their ninth year and the results for the tenth year have now been published.

The three clones, BD 2, BD 5, and BD 10 were rested from June to October, 1927, in order that budwood might be taken from them. The trees came once again into tapping in November, but on this occasion only about half the number were available, the other half being left at the disposal of the estate for budwood purposes. During November and December the yields showed considerable increase, but on account of the five months rest these figures were neglected and the yields determined over 1928.

The tapping system employed was alternate daily on one-third of the circumference.

The results for 1928 are given in Table XXV.

TABLE XXV.

Clone.	No. of trees.	Grms. dry rubber per tapping.	Lb. per tree per annum.	Yield 1927 / Yield 1928
BD 2	16	48.5	17.1	1 : 1.18
BD 5	8	71.6	25.0	1 : 1.43
BD 10	48	52.6	18.6	1 : 1.19

Throughout the tests the trees have remained free from disease. The growth is excellent and, in their eleventh year, the trees are better grown and taller than seedlings of the same age. The bark properties are completely satisfactory: in one tree tested by chance the bark in tapping was more than 12.5 mm. thick, while the renewed bark after one year was already 8.5 mm. in thickness. BD 5 is an especially attractive tree and the only exceptional feature noticed was in BD 10 where the latex was thicker than ordinary owing to its high rubber content.

The Tjirandi clones have sprung into prominence owing chiefly to the very high yields reported for the best of them, Tjir. 1.

This clone was also tapped from June, 1927 to May, 1928, with the exception that tapping was suspended during the dry month of August while in the following month only shallow tapping was employed. For the remaining ten months the average daily yield per tree was 83.7 grms. of dry rubber. When the test was continued, however, it was found that the clone possessed the strongly marked character of producing at a much lower level than the average during the dry months of August, September, and October. This is well shown by the yield figures for the three trees of the clone which were obtained in 1928: these are shown in Table XXVI.

TABLE XXVI.

No. of tree	119	34	33	120	230	Average.
Jan.	74	74	93	69	57	77
Feb.	96	97	83	70	59	81
Mar.	90	137	134	141	85	109
April	115	103	117	101	108	111
May	—	130	115	111	88	91
June	—	98	82	101	83	75
July	93	72	61	79	70	75
Aug.	28	17	50	34	38	33
Sept.	31	30	53	38	36	38
Oct.	41	40	35	31	29	33
Nov.	65	83	29	87	65	66
Dec.	72	80	73	94	137	89
Average for year: grms. dry rubber per tapping						76.5

The figures need some further explanation. The tapping system at the start was the usual one-third cut alternate daily but in October this was changed to a quarter cut on a new panel at a height of 30 ins. Further, tree No. 119 became attacked by Brown Bast and was rested during May and June after which tapping was resumed on the new panel. Brown Bast was not seen again nor were any other exceptional features observed.

A few records were taken of the yields on the new panel in January, 1929, as shown in Table XXVII.

TABLE XXVII.

Tree No.	119	34	33	120	230
Jan. 8th	47	57	46	54	77
Jan. 16th	43	64	47	57	71
Jan. 23rd	44	—	—	—	74
Jan. 29th	36	—	—	—	54
Average.	42.5	60.5	46.5	55.5	69.0

The incompleteness of this Table is the result of a particularly unfortunate occurrence. On January 21st of this year the field, G 3, in which the trees were growing, was swept by a wind storm which blew down three of the five trees of clone Tjir. I leaving only 119 and 230 intact. It should be emphasized, however, that buddings were not the only trees to suffer, for the whirlwind destroyed most of the trees in its path. The only satisfaction to be extracted from this disaster was a further instance of the union being the strongest part of the trunk for in no case was a budding broken at the union.

Tjirandi Estate has other good and medium clones of which Tjir. III with an average yield of 42.3 grms. of dry rubber during 1928 is the best. In point of yield it is very close to BD 2, while clones VIII, IX and X are not far below. Moreover, during the tests of 1928, another clone XVI was discovered with the high production of 60 grms. of dry rubber per tapping. While it does not yield so well as Tjir. I in the wetter months, its yield does not fall to the same extent in the dry period. Further details to this clone will therefore be awaited with interest.

Tjir. I is a strikingly handsome clone which, like BD 5, Av 49, and BD 10, is easily recognizable at a distance, both in the young and older stages, by its characteristic leaf form. It produces the most strongly growing buddings that the writer has yet encountered.

IV.—The Present Position Examined.

It might be advantageous at this point to review the evidence furnished by the work already described in order to ascertain what conclusions of practical importance may legitimately be drawn from it. From the very start the budding method has had to meet an extraordinary amount of opposition not all of which has been unjustifiable. The experienced planter, who has been accustomed for years to dealing with material raised from seed, generally finds it difficult to adjust himself to a situation in which an entirely different planting unit is employed. His constant anxiety is as to whether the new material will reach and maintain the standard he has long been accustomed to and his uniform tendency is to exaggerate the difficulties of the method.

Where this attitude is not due to prejudice or to *laissez faire* it is to some extent both reasonable and explainable. A planter is always justified in subjecting to thorough criticism any new planting method and where a perennial crop is involved, as with Hevea, a conservative attitude is fully justified. Unfortunately in the past the planter has generally been isolated from reliable sources of information and has been obliged to accept as a substitute authorities which often furnished personal opinions strongly prejudiced with respect to innovations.

But planting problems can be solved neither by opinion nor experience limited to a few estates, or even to one country, and the present section, therefore, is intended to summarise the evidence from the practical experiments carried out in all rubber producing countries.

(*a*) *The Yields of Buddings.*

So far as the main question of yield is concerned the fact stands out that, age for age, up to 11 years, certain clones furnish yields which are greater than can be obtained from the best seedling material at present available. That is to say, at the present time budding is not merely the best but the only method of obtaining a given stand of uniformly high-yielding trees. This uniformity is strikingly illustrated by the figures for Tjir. I (Table XXVII). Occasionally, on many estates, individual seedling trees are encountered which at the age of 11 years give greater yields than 25 lb. of dry rubber per annum but the fact remains that there is no method of reduplicating this property on a given area except by budding.

Again, many clones have been shown to give over 2½ lb. per tree per annum at the age of four years, 6 to 8 lb. at six years and 11 to 18 lb. at nine years. There is a wide range of proved clones—A.V.R.O.S., Bodjong Datar, Tjirandi, Prang Besar—from which a selection can be made which, if the trees are grown 80 to the acre, should furnish yields of at least 500 lb. per acre in their sixth year, 800 lb. in their seventh and at least 1,000 lb. in their tenth year.

The oldest buddings which have been carefully test-tapped are not yet 12 years old. So far as the most superior of these are concerned the yield has continued to rise at a more rapid rate than that characteristic of seedlings and no slackening off has yet been observed. The yield for the Bodjong Datar clones, for example, is still rising rapidly in the eleventh year. In this connection it should be remembered that the best method of tapping buddings has not yet been worked out.

Heusser and Holder have very recently published results obtained by tapping three clones on a new system.[49] This was a two-cut system, the cuts each being one-quarter, placed step-wise above the other at a distance of a metre, the upper being two and the lower cut 1 metre above the union. The upper cut was placed to the left of the lower one, and, when the latter reached the union, a fresh quarter panel was marked out to the left of the original upper cut which now automatically became the lower.

In this manner, tapping daily in alternate months with a bark consumption of 1¾ ins. per month, a bark renewal period of 14½ years is allowed for.

The system is scientifically grounded for it takes account both of the course of the latex vessels tapped and the area of bark which is drained during tapping. That is, each cut draws on a separate set of latex vessel rows and drains an area of bark which does not overlap that drained by the other.

The experiment was carried out on 100 buddings each of clones 51, 65, and 80; as controls two groups of 200 seedlings of the same age were used as well as 50 buddings of clones 65 and 80, and 100 of clone 51.

The controls were all tapped on one-third, the seedlings at a height of 62.5 cm. and the buddings at 80 cm. Tapping was daily in alternate months, the controls being tapped in the odd months and the buddings with two cuts in the even months. The experiment was carried out on the Boekit Maradja Estate.

So far as the controls with the one-third cut were concerned, the buddings were all better than the seedlings the proportionate yields being as follows:

Seedlings: clone 51: clone 80: clone 65=100: 142: 170: 183.

Again putting the yield of the buddings tapped on one-third equal to 100 then the yields on the double cut system for the three clones were 135, 121, and 151 for clones 51, 80, and 65 respectively. To obtain a comparison of all the experimental groups and both systems of tappings the annual yield for 200 trees of each is computed in Table XXVIIa.

TABLE XXVIIa.

Tapping System	Yield per annum of 200 trees in lb.			
	Clone 51.	Clone 65.	Clone 80.	Seedlings.
one-third.	952.8	1,224.3	1,135.3	675.3
two cuts.	1,334.3	1,915.9	1,425.2	—

The yield of the upper cut varied in the three clones from 88 to 92% of that given by the upper cut, so that if the shorter length of the upper cut is taken into account both cuts yielded independently of one another almost the same amount.

In conclusion Heusser drew attention to the fact that clone 65, tapped with two cuts, gave an average yield of 9½ lb. per tree for the year in its sixth year although it was only an average clone. He thought, therefore, that the tests should be continued to ascertain whether the better clones could be tapped in this fashion without damage to the trees but that, meanwhile, the possibility was opened up of obtaining increased yields even from average clones.

(b) Proving New Clones.

The question then arises as to whether the work already carried out has established a sufficiently large number of good clones for the needs of the plantation industry or whether the search for others should be prosecuted further.

The answer to this is that the superior planting material of to-day is merely the best which has been proved up to date. There is no guarantee that it will not be improved upon in the future, in fact the evidence is all to the contrary. The A.V.R.O.S. Experiment Station, for example, is now putting out in small quantity clones which are reported to be better than their original selections. Naturally there will be a limit but research must continue until this is in sight.

Successful budding from a high-yielding mother tree does not always produce a successful high-yielding clone, nor is it possible to decide the success or otherwise except as the result of a tapping test. Such a test can be carried out at the earliest three years from the date of budding and this is an additional reason why clone testing should always be on a small scale. Ten trees of a clone are sufficient and the number should rarely exceed 20. It should be kept in mind that if a clone turns out to be a failure the result will be just as obvious from 20 trees as from 200. To quote the Pilmoor buddings as an example, 21 clones were planted out in an area of 12 acres. Tapping tests have shown that four of these are good, two or three medium and the rest worthless. Data for one of the latter are given as an example in Table XXVIII. The figures are for alternate daily tapping in April, 1929.

TABLE XXVIII.

No. of trees in clone	130
,, ,, ,, tapped	20
Average yield per tree per tapping	3.04 grms.
,, ,, best ,, ,, ,,	6.4 ,,
,, ,, worst ,, ,, ,,	1.2 ,,

These figures demonstrate clearly that the value of the experiment has not been increased by increasing the number of trees in the clones; in fact the same results might have been obtained by employing one-third of the occupied area, an important consideration where land is scarce or valuable.

The first tapping in a clone trial need not be regarded solely as a means of separating the promising clones from the poor ones. There is now sufficient evidence that a good estimate of the potentiality of a clone can be obtained from a light tapping, say for three months, in its fourth year. The indication is certainly good enough to justify, in a promising case, the establishing of a budwood nursery so that no time shall be lost if subsequent tests confirm the first judgment.

At the same time, a test-tapping to be of any value for grading clones exactly must be carried out for at least 15 months. It is necessary to have the overlapping three months to gain some indication of the behaviour of the clone in the second tap-year.

(c) *Budding and Disease.*

Secondly, the evidence is now overwhelming that budded stock is on the whole as healthy and strong as seedling material and is no more susceptible to fungus or insect attack. Certain clones have been described as particularly liable to Pink Disease but this is probably due more to their type of branching than to any inherent liability.

The question of susceptibility to Brown Bast is in another category as practically nothing is known about the nature of this disease. It is however definitely connected with a heavy drain on the latex of the tree and is an almost inevitable consequence of overtapping but as to its heritability there is as yet no evidence. One of the Pilmoor clones was deliberately selected from a mother tree known to be infected with Brown Bast. Up to the present there has been no sign of it in the buddings but these are, unfortunately for this particular point, not normal. The bark shows a very pronounced tendency to form nodula outgrowths and becomes very irregular in consequence, but whether this is a consequence of parental infection or not is uncertain. From a practical point of view, however, there is only one attitude to adopt until more evidence is available. Brown Bast must be assumed to be capable of being transferred from an infected mother tree to its budded offspring and such mother trees should not be budded from.

(*d*) *Buddings and Wind Damage.*

The question of the strength of the union can now be regarded as definitely settled. At first it was considered that this must necessarily be a place of weakness although this reasoning might have been seen at once to be fallacious from analogy with the budding and grafting of other woody trees. As a matter of fact the union of the stock and scion is so complete that it forms a zone of strength rather than weakness. Indeed, from the time the young bud begins to sprout it is so intimately connected and keyed into the wood of the stock that subsequent weakness at the union is impossible.

The writer has seen several cases where budded areas have been swept by sudden wind storms but in no case has seen a break at the union. The experience with clone Tjir. I was similar and is the general thing. In violent storms buddings generally break where one would, on mechanical grounds, expect the fracture to occur, that is, about four or five feet from the ground, but quite frequently a budding will be uprooted with the union still intact. So far as the trunk is concerned there is no evidence that buddings suffer from wind damage more than seedlings, but there is no doubt that certain clones possess branching systems which render them more than ordinarily liable to wind damage. This weakness may depend upon the angle which the branch makes with the trunk, the shape of the crotch and the form of the junction of branch and trunk. Naturally, the liability to branch damage may be increased by vigour of growth in the crown, so that a clone like Av 36 which is ordinarily liable to wind damage becomes less so when planted in poor situations where growth is slow.

(*e*) *Bark Characters and Bark Renewal.*

Thirdly, all the evidence bearing on the quality of the bark and its renewal is completely reassuring so that it is now difficult to imagine how the opinion arose that, as a rule, the bark of buddings was thin and unsatisfactory and failed to renew properly.

Reviewing what has been said and done with regard to this very important question, Heusser in his first account of the tapping of A.V.R.O.S. buddings said that, so far as his observations went, bark renewal left nothing to be desired.(6) Nevertheless, with scientific caution, he went on to say "It is, however, not impossible that in the course of time it will turn out to be less good than in the case of well-developed seedlings and that budded trees will have to be allowed a longer period for bark renewal than trees grown from seed." Again, in his second account of the tapping of A.V.R.O.S. clones(10) he stated that the renewal seemed a little less vigorous than that of strongly growing seedlings. Of clone 50, however, he said, "This is not so . . . the bark renewal is as good as that of seedlings. The oldest renewed bark, now two years old, has an adequate thickness and the panels are beautifully arched . . . ." In clones 80, 52 and 36 renewal gave no cause for anxiety but was observed to be slow in clone 33 growing on clayey soil. In a later account of the clones on Boekit Maradja Estate, Holder and Heusser[20] discussed the quality of the bark in clones 51, 80, 71 and 152. In this case Av 80 was quite satisfactory the renewed bark having a thickness of 6 mm. after 16 months: Av 51 had thick bark and good renewal while in Av 71 and 152 the primary bark was 8 mm. in thickness and the renewed bark after 16 months was 6 mm.

In the case of the Bodjong Datar clones, Gunst[39] reported that, after two and a half years, the renewed bark of the buddings was actually better than in seedlings of the same age; the writer has already given the results of his own observations of the 11-year old buddings on Bodjong Datar.

The great difference between the virgin bark of buddings and that of seedlings is that the amount of external cork is much less in the former case. The amount of yielding cortex is not actually less but the absence of a well-developed cork layer lessens the amount of support for the tapping knife and tends to keep the cut flat. In consequence buddings need care in tapping while, to avoid the spilling of latex over the edge of the cut, this should have an inclination of 35° or more to the horizontal.

A valuable contribution to our knowledge of the bark renewal of buddings has recently been made by Billington.[48] Employing a depth gauge he made measurements in July, 1928, of the thickness of the renewed bark of the panel surface at places where tapping had taken place about half, two, four and six months previously. Similar measurements were again made in January, 1929, the bark strips measured being respectively about one, three, five, seven, nine and eleven months old after tapping. 58 trees from four different clones were measured, three of which were good yielders and one poor, and Billington made the interesting observation that the individual clones maintained the same position relative to the general average bark thickness at both dates of measurement, that is, one of the good clones was consistently above the average, the other two close to it and the worst clone consistently below. A striking feature was the rapidity of the renewal process during the two or three months after tapping and the gradual slowing down of the process after this until, some six months after tapping, it progressed only a little faster than the virgin bark. Seven months after a strip had been tapped there was over 70% of renewal even in the worst clone.

TABLE XXIX.

	Virgin Bark		Renewed Bark			
			Tapping Month 1928			
			Feb.	April	June	Aug.
Bark thickness	6.9	6.5	5.5	5.2	4.7	4.3
Per cent renewal	—	—	82.0	77.0	71.0	67.0

A selection from Billington's figures is given in Table XXIX. These were obtained in January, 1929, from the worst clone. Tapping had been carried out during 1928 so that the figures apply to the renewed bark tapped approximately eleven, nine, seven and five months earlier. The figures form a complete reassurance that the bark of buddings is not only adequate for tapping but also exhibits a satisfactory rate of renewal.

It is important to remember that even the earliest buddings are not yet old enough to have allowed tapping tests to be carried out on the panel of renewed bark. Results of such tests are required before the question of bark quality can really be regarded as closed.

(*f*) *The "Elephant Foot."*

The question of the "elephant foot" developed below the union does not merit consideration. It is no disadvantage from a practical point of view and the only objections advanced against it are based on "aesthetic" considerations derived from contemplation of the normal seedling tree of the plantation.

The question of the planting policy to be adopted in the light of the experience of the last decade is so important that its discussion is delayed until a later chapter.

V.—The Budding Method.

(*a*) *The Principles Underlying the Method.*

As practised at the present time the budding of Hevea is a modified form of patch or shield budding. In this, a rectangular panel of bark is removed from the stock at a point where normally no bud is situated. The panel is replaced from the budwood by a correspondingly shaped patch which contains a bud.

To carry out the operation successfully some knowledge of the process is essential and, to serve as a foundation, a brief sketch of the course of events in the successful patch-budding of a wild rose stock with a bud from a choice variety follows. The panel is cut at a time when there is considerable growth activity in the stock. The cut is made down to the wood and when the flap of bark is pulled back all the tissues external to the wood, including the active cambium, are removed. When the patch is placed in position the success of the operation depends upon two phases of activity proceeding rapidly and succeeding one another without break. The first phase is one of wound healing and, in this, growth takes place chiefly from the side edges of the cut to form a mass of tissue known as wound-callus. Similar tissue grows outwards from the wood towards the bud-patch and from the edges of the latter to meet the growth coming from the side-cuts. If the proper conditions have been chosen, this formation of wound-callus is very rapid and an intimate connection of the patch to the stock is quickly brought about. The next phase consists of the development of a new cambium layer connecting the old cambium at the cut edges, through the wound tissues at the union, to that of the bud-patch. The growing tissues of the bud are in connection with this cambium which, from this point, forms an integral part of the stock. In other words union is complete.

In the budding of Hevea it is found that this typical process of union is modified in some important respects. The flap is still cut and removed while the stock is in an active state of growth and, in order to do this, the cuts are made down to the wood. For successful stripping the cambium must be in an active condition: if it is resting it is not possible to peel off the bark. This applies both to the stock and the budwood.

Hitherto it has been held that when the flap or tongue was pulled back most of the cambium remained on the stock and played a prominent part in the union process.[44] Moreover, de Vries has given the results of experiments which showed that when the surface of the exposed wood of the stock was carefully scraped before the bud-patch was inserted, it was impossible to obtain a successful budding. This was ascribed to the absence of the cambium of the stock due to the scraping.[36]

As a consequence of recent work by Mann[45] these views must now be relinquished and the results described by de Vries given a different explanation.

If the flap is removed from an actively-growing stock and a transverse section through the panel examined under the microscope, it is actually impossible to be certain whether the two or three outermost layers of cells are cambial or the newest formed layers of wood cells, but in spite of this it has generally been assumed that most of the cambium remained on the stock.

According to Mann, the first stages of union are accomplished by the development of a wood callus, produced certainly from the exposed surface of the wood but in the formation of which the end cells of the medullary rays are most active. These produce rows of cells which grow outward until they interlock with similar cells produced from the cambium of the patch. It was no doubt these important active medullary ray cells which were scraped away or killed in the experiments described by de Vries. If any cambium cells are left on the wood they will, naturally, assist in completing these early stages. The interlocking of the cells mentioned gives rise to an irregular parenchymatous tissue which normally connects the patch completely to the stock in seven days by filling up the space between the stock and bud-patch.

During this period a normal wound-callus is developed between the edges of the bud-patch and those of the bark of the stock. About three weeks after budding a cambium develops in this tissue and connects the cambium of the patch with that of the stock. The reconstitution of the cambium is normally completed about four weeks from the date of budding.

It is obvious that the shorter the gaps on all sides between the edges of the bud-patch and of the panel on the stock, the quicker will be the process of cementing the edges with wound-callus and the better the prospect of a "take." So soon as this connection is established the growing tissues of the bud are put in connection with the cambium of the stock and the bud is in a position to commence active growth as soon as the proper conditions are present. These are not entirely conditions of soil or weather. It must be remembered that in the Hevea seedling of 10-12 months the most vigorous bud is the terminal one. While this is elongating rapidly it dominates the growth of all the buds behind it. These are unable to grow out at all until the terminal begins to lose this dominance which it gradually does from its second year onwards. Again, the lower buds differ greatly amongst themselves in growth-potentiality but generally speaking the lower down the stem the greater the degree of dormancy or growth weakness. The situation may best be visualised by regarding the bud on the patch as unable to grow out until the dominance of the buds above it is removed. This can be done by cutting a bark ring immediately above the union which has also the effect of making the young transplanted bud a terminal. The influence of this ring is, however, not lasting. As soon as the healing process has gone far enough to enable water and food supplies to proceed again normally to the parts above the ring, the influence of the buds near the apex begins to make itself felt again and the bud below the ring is retarded once more. It is therefore necessary to cut back the stock at least to the ring so that the young budding can assume the leadership and take on the terminal growth.

From this point the young shoot makes every effort to grow vertically. Although there is no doubt that ultimately it will take up the vertical position an ugly bend or malformation will be produced at the union if anything is allowed to act in the early stages in such a manner as to attempt to prevent it from doing so. Thus, if the cutting back of the stock is delayed, a very decided bend is produced at the base and, in correcting this, an exaggerated "elephant foot" is produced below the union.

Both operations, i.e., ringing and cutting back, tend to stimulate the budding to grow out. In ringing, however, the stimulus is not nearly so strong as in cutting back and tends rather to force the bud into slow and gradual growth. On the other hand, cutting back is a strong stimulus, the bud being forced out rapidly into strong growth.

Before the young budding finally takes up its erect habit and begins to develop like a normal tree it cuts off connection with the "snag" or portion of the stock which is left after cutting back. Soon after the pruning cut is made a layer of gummy substance is formed in the cells just behind the cut. Behind this gum a layer of cork is formed and in time the "snag" would become detached leaving a circular scar to be sealed over by the growth of wound tissue and the activity of the cambium of the stock. It is obvious that the smaller the scar the more rapidly will it be healed over and the less will be the swelling at the union.

An understanding of the above phases is essential to a proper knowledge of the technique of budding, for the stock and scion must be manipulated so as to take advantage of the different reactions described above if it is desired to produce a strong and shapely plant.

(*b*) *The Operation of Budding.*

It must be understood at the outset that budding is a skilled operation in which the personal element is involved to an extent which over-weighs any other factor or consideration. The skilled operator has a conscious or subconscious knowledge of the various principles involved and his hand and eye are so co-ordinated that, without actually being aware of it, he can apply his technique to fit them. No amount of supervision and instruction can ensure that a man will make an efficient budder. After he has seen a demonstration the only course is to allow him to carry out a number of buddings and judge him by the result. It is only in very obvious cases that a man can be seen to be budding incorrectly, and frequently two men, side by side, both apparently working equally well, will produce very different results. The operation is an individual one; the whole of it should be carried out by the same man and not sub-divided amongst the members of a gang.

VI.—The Choice of Stock Material.

(a) *Choice of Material.*

Before contemplating operations on any considerable scale efforts should be made to obtain seedlings for use as stocks of the most uniform growth possible. The best age for these is between 10 and 13 months but the amount of growth made by the seedlings is more important than their actual age. They should be at least 1 in. in diameter at a height of 4 in. from the ground; stocks of ¾ in. diameter may be budded but they are only large enough to permit of one attempt which is a serious disadvantage if the first one fails.

There is actually no limit to the size or age of the stock but after the age of two years the operation becomes increasingly difficult owing to mechanical factors such as the thickness of the stock bark and the difficulty of fitting and binding the bud-patch. It is therefore inadvisable as a rule to attempt to bud stocks older than two years. If the budding is being done in the nursery, the age of the stocks should not exceed 13 months for if these are later to be transplanted as stumps the operation is more troublesome than usual owing to their size and the risk of casualties is greater.

The question is often asked as to whether it is best to use stocks from "selected" seed. Little is yet known of the effect of the stock upon the scion in Hevea as will be emphasized later and there is as yet no evidence that seedlings from "selected" seed have made more suitable material for budding upon than ordinary "unselected" seedlings. Uniformity and vigour of growth are apparently more important than any factor derived by the stock from its mother tree. Naturally, these two qualities are more likely to be secured from a carefully chosen sample of seed than otherwise but apart from this there is no gain so far as can be seen at present.

(*b*) *Budding of Stumps.*

Another important question is the possibility of using stumps as stock material. Very varying experiences are reported as a result of budding on stumps and most of these have resulted in failure. Fortunately, there is definite experimental evidence on this point which has been investigated by Vrolijk at the Tjiomas experimental garden in Java.[37] His results may be summarised as follows: One hundred seedlings each about the thickness of one's thumb were stumped at 1 metre from the ground and planted out in the usual way. At intervals of 5 to 15 days batches of 20 stumps were then budded. In the first four batches, budded respectively 10, 20, 30 and 40 days after stumping, not a single success was obtained. At 50 and 60 days, when the stump was just beginning to show signs of terminal growth, 8 successes were obtained and 15 days later a single success. At 70 to 84 days from the start, by which time the terminal of the stump had made some growth, no successes were again obtained.

About five months from planting by which time the stumps had made 1½ metres of growth, it was possible to get 11% of successes, and when the stumps had been seven months in the ground, the percentage had risen to 98% which was about the same percentage as that originally obtained with the un-stumped seedlings and also with seedlings budded about the same time (seven months) from the start of the experiment.

It was therefore concluded that eight months after transplanting, when the stumps had produced about 2 metres of terminal shoot, the normal satisfactory percentage of successes could be obtained.

Results agreeing with those of Vrolijk have been reported by Mann[46] who found no significant difference, when budding in the field, between stumps and basket planted seedlings where the former were well established. Mann's results are summarised in Table XXX.

TABLE XXX.

Clone.	Final Successes.	
	Stumps.	Seedlings.
No. 1	67 %	66 %
No. 2	61 %	65 %
No. 3	59 %	61 %

These results are more or less in accordance with what one would expect. In the planting method known as stumping the young plant is deprived of all its lateral roots, and at the same time, by means of the pruning cut, a strong stimulus is given to the next bud below the cut to grow out and take up the function of the terminal bud which has been removed. It is unable to do this until new feeding roots have been developed and, while this is taking place, shoot growth is at a standstill owing to the transport of water and food materials from the root being at a minimum. During the same period cambium activity is also at a standstill and the conditions for a successful union do not therefore exist. When root activity is again restored the terminal bud is able to grow out. In doing so it dominates the situation until the snag has been thrown off and healed and the stump has become a normal plant again with a normal transport of water and foodstuffs. By this time, which is about six months after transplanting, budding may be undertaken with a reasonable prospect of success, but it is useless attempting to bud when the energies of the stump are being mainly directed to recovery from the shock of the stumping operation.

VII. Budwood.

(*a*) *Collecting the Budwood.*

The collection of budwood from a high-yielding mother tree is an operation which is generally far from simple. The branches should have a thickness approximately equal to that of the stocks and their diameter should not, as a rule, exceed 1½ ins. nor be less than ¾ in. It is astonishing how few suitable branches occur on some mother trees and difficult of access they may be.

The lower, horizontally-growing branches are most frequently of very little use, the most suitable ones being the succulent leaders growing almost vertically in the upper parts of the tree and therefore difficult—often impossible—of access. Provided that a year's notice is available these difficulties can be overcome by pollarding, i.e., cutting hard back some of the secondary branches of the mother tree. The branches should be 6 to 9 ins. in diameter at the point of cutting and as far as possible should be on the more open side of the tree.

The cut made is the ordinary sloped saw-cut which is tarred over afterwards. Very shortly, from behind the cut, a ring of fresh shoots springs out. These are frequently very numerous and crowded, and not more than five or six should be allowed to grow. This gives a possibility of four or five branches of budwood with one or two to leave behind in order to continue the growth of the pollarded branch if required. The number of branches to be pollarded depends upon the age of the tree and its type of branching and no rule can be laid down for the manner of performing it. Generally, however, it is inadvisable to pollard more than six branches of an average tree.

In producing budwood on a commercial scale this method is too unreliable and does not furnish material in the large quantities required. Use is then made of so-called multiplication nurseries, a subject which will be returned to at a later stage.

If budwood is being taken from mother trees on the estate itself the branches should be marked down before they are needed and strips of red or white cloth tied on them. The actual cutting is best done on the morning of the budding, although, if required, the cutting may be done the previous evening provided all leaves are immediately cut off, the branch cut up into separate sticks 2 to 3 ft. in length, the sticks placed with their lower ends in water and the vessel stored in a cool place overnight.

(*b*) *Judging the Budwood.*

Before cutting the budwood it is essential to test it in order to ascertain whether the bark will strip easily or not. Unless the bark will come easily away from the wood, the bud will almost certainly be injured during the removal of the patch. The bark will strip most easily while the branch is actively making extension growth which is the period just before the flush of light green leaf is seen at the terminal end. A good deal of assistance can be gained by watching the terminal growth made by seedlings from five to ten months old in a nursery. It will be noticed that some of these end in a group of fully formed dark green leaves in the middle of which the hard, shiny, dark green terminal bud can be seen. If this is watched for the next few days it will be seen to put up a further "storey" of shoot-elongation with a group of tiny leaves at the top. It takes about 17 days to complete this "storey" and, while it is doing so, the leaves at the top make very little growth. Suddenly elongation stops and the energy of the shoot for the next 17 to 20 days all goes into developing the leaves to their full extent. The end of this period is marked by the leaves becoming almost horizontal. While the leaves and stalks are developing to full size they change in colour from brown to light green and the leaf blades hang downwards, and, while growing into the horizontal position, they change gradually in colour to dark green. During the latter stages the hard shiny terminal bud once more becomes visible and a short resting period is again entered.

Similar growth periods can be noticed on the extension shoots of the tree and opportunity should be taken of cutting those which are making active extension growth. The advantage of pollarding is that the stages are shown very clearly by the new shoots.

(c) *The Choice of Buds.*

The question of the kind of bark which is best to use will be fully discussed later; for the time being it will be assumed that none but the brown bark is being used. The problem of the choice of buds now comes in and this has not yet received the attention which its importance merits. It is well known that in extensive budding operations there are often a considerable number of unexplainable failures. These are generally due to faulty technique or workmanship but even when these are beyond criticism unaccountable failures still occur. Again, in certain cases where the budding has actually been successful the young shoot obstinately refuses to grow out and when growth ultimately does take place the resulting shoot is weak and spindly.

Some failures are due to useless buds having unknowingly been taken and it is necessary to be able to detect these beforehand.

Every bud is produced originally in the axil of a leaf, that is, deep in the angle between the branch and the swollen base of the leaf-stalk. In time the leaf dies and falls away leaving beneath the bud a scar which is roughly the shape of the under side of a horse's foot. As the branch increases in thickness this scar becomes greatly stretched in the direction of its width and much shorter in length until, when the branch exceeds 1 in. in diameter, it may only be an indistinct line.

Most of the buds on a branch are shoot buds from which, after leaf-fall and a period of rest, the future side branches are formed. Obviously, all do not become branches; some are fated to lie dormant for years whilst others, after making the beginnings of growth, die-back completely. In such a case as the latter a small rounded boss is left where the bud originally was situated. These "stillborn" buds are often budded on to stocks in error. When a patch containing such a "stillborn" bud is placed on the stock a normal union takes place but the growth from it is delayed and abnormal. After a considerable time—frequently months—either one or two weak spindly shoots may develop from dormant buds which would not, ordinarily, grow out. These "stillborn" buds should therefore be avoided.

In older wood a few of last year's buds may have produced flowering shoots. If the flowers were fertilized and produced fruit, the shoot when shed would leave a cup-shaped scar. If the flowers are not fertilized the shoot falls off early and the scar is more diamond-shaped. There is no bud left at a scar of this kind and it is useless to include it in a patch. Chinese budding coolies seem to be able to recognize these different buds and all who are concerned in budding should make themselves familiar with them.

VIII.—Materials Used in Budding.

The materials necessary to have on hand for the operation are:

(1) *Knives*—

Two knives are generally necessary for each operator. The first should be of the "parang" type, as nearly as possible the size of a carving knife. This is required for cutting off the piece of wood and bark from which the bud-patch is to be stripped and both hands are required for using it. Some persons prefer a smaller one of clasp-knife size which is used with one hand only.

The second knife is the budding knife proper. The special type of knife fitted with a bone tongue at one end is too well-known to need description and is very popular. These knives can be obtained from the firm Carl Schlieper of Medan, Sumatra, and from local estate agency firms.

It should be remembered that the personal factor is involved to a considerable extent in the choice of knives. Some workers use the special budding knife for cutting off the buds from the budwood as well as for carrying out the budding operation. Many Chinese use an ordinary cheap two-bladed penknife. In Java the almost universal practice is to use the special budding knife alone.

(2) *Budding Wax*—

In the past it has been the practice to recommend as budding wax a mixture of paraffin wax and petroleum jelly. There is, however, a certain amount of risk involved in employing ordinary commercial grades of paraffin wax. These sometimes contain free hydrocarbons of the kerosene type which are capable of penetrating the bark and killing the tissues. This is all the more likely to happen to field buddings or to those on the edges of the nursery where the direct heating effect of the sun is more intense. Up to the present the special wax "Entwas" marked by the Asiatic Petroleum Company has given no cause for complaint. It is readily obtainable locally and, moreover, in many ways it is convenient to have a specific trade preparation which can be used directly.

(3) *Budding Cloth*—

This cloth, which is used after being impregnated with the molten wax, may be nearly any kind of cheap unbleached calico. It should not be too fine and muslin-like or it will not hold the wax nor should it be too heavy or it will take up too much of it.

The cloth is used in strips which should be about 1 in. in width and 20 ins. in length. To soak the cloth, first cut the large roll into lengths of 20 ins. and roll these tightly to form smaller rolls 20 ins. in width. The cakes of "Entwas" may be cut up into about a dozen smaller pieces and placed in a tin vessel a little taller than 20 ins. This vessel is placed

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in one slightly larger containing boiling water which can be placed over a fire. The rolls of cloth are then placed in the wax three or four at a time, and kept there for at least 20 minutes after which the rolls are withdrawn and the superfluous wax allowed to drain away. When cold, the roll may be cut or torn into strips of the required width. These are made in tiny rolls which are ready to apply to the budding. Before being rolled up any superfluous wax should be scraped off with the back of a knife.

Care should be taken to see that, when bought, the cloth contains no "dressing" or "filling." Such cloths often contain inorganic deliquescent salt, such as magnesium chloride, or antiseptics, the most popular of which is zinc chloride. It would be necessary to wash and dry a cloth of this type which would be a troublesome addition to the labour.

Binding on the bud with waxed cloth is only very rarely practised in Java where the use is preferred of fresh, narrow strips of the fibrous outer skin of the leafstalk of *Musa textilis.* This is the well-known plantain which yields Manila hemp which is prepared from the fibres which occur in the leaf-stalk. For budding purposes the leaf is cut freshly from the plant, the soft pithy part scraped away with a blunt knife and the layer which remains torn into strips of the required width. These form an ideal wrapping; the material is soft and pliable and as it contracts slightly on drying this tends to keep the bandage tight. Manipulation is easy; the binding is put on spirally from the bottom and the upper end secured by passing it under the last two turns and finishing off with a simple twist which prevents slipping.

The use of wax and cloth as binding materials increases the cost per budding very considerably and it is important that, in Ceylon and Malaya, attempts should be made to ascertain whether Manila hemp or some other vegetable material cannot be substituted for the more expensive wrapping.

One very important claim is made for Manila hemp. Frequently buddings wrapped with waxed cloth prove unsuccessful owing to included moisture encouraging bacterial or fungal rot of the patch. It is claimed that with Manila hemp the ventilation is so good that losses due to this cause are practically nil.

(4) *Working Box*—

First recommended by Gough, a working box for each budding coolie will be found very useful.[11] It is an ordinary wooden box about 12 ins. by 7 ins. and 6 ins. deep which has half the top covered over. The latter serves as a small working table while the knife, rolls of binding tape and labels can be kept in the box.

IX.—The Operation of Budding.

The technique of budding is specialized and individual in character and anything which tends to detract from this makes for non-success. The operation is a one-man job depending not so much on mechanical assistance as on a fine co-ordination of hand and eye. It is for this reason that division of labour should be reduced to an absolute minimum. In the actual operation itself there should be none, for if more than one person is involved resulting additional handling of the material increases the risk of damage and failure and makes it impossible to determine responsibility for the latter. A further important consideration is the slowing down of the operation which increases the cost per acre—already sufficiently high.

Outside the actual operation a boy can give useful help by going on ahead to clean the bases of the stocks and, later, by following up to put on the leaf shades as fast as the buddings are completed.

In doing this he must not be allowed to bend the stock in order to reach the higher leaves. If this is done there is a risk of loosening and moving the bud-patch. Some undertakings provide him with a long-handled sun-shade which he sticks upright in the ground so as to protect the work of the budding coolie from the sun until the bandage has been put on.

The estate manager can ensure that three important factors for success are present, namely, actively growing stocks, good budwood, and suitable binding material, but unless the budding coolie is expert and follows a sound routine it is useless to attempt budding on a plantation scale. The steps in the latter are described below and the supervision should be sufficiently adequate to ensure that they are followed.

(1) *Cleaning the Stock—*

The budding coolie should be provided with a lump of rag or cotton waste. With this he rapidly removes any incrustation of soil from the bottom 6 ins. of the stock. The cleaning should be carried right down to the collar.

(2) *Cutting the Bud Panel—*

First a vertical cut 2½ ins. long is made on the side of the stock to within a distance of 1 in. from the collar. The cut is made down to the wood, the feel of the knife announcing when this is reached. Then a parallel vertical cut, ¾ in. from the first, is made and the two joined at the top by a horizontal cut.

When these cuts are made there is an outflow of latex which should be allowed to run and coagulate before the panel is opened. It has become almost a general practice for the budding coolie to cut in advance 10 to 20 panels. He then goes back to the first and wipes off the latex with a rag before opening the panel. Later in the day this becomes unnecessary and the rate of progress is correspondingly increased. Scrupulous cleanliness is essential throughout and the latex should not be allowed to get on the hands, knife or binding strips.

When budding is being carried out in the field the panel should always be cut on the north side of the stock. Also, if the operation is carried out in the nursery the stumps when planted out should be set with the young bud facing north. This is an important detail which makes a great deal of difference to the degree of success and, later, to the rate and growth of the young bud. Hevea is very sensitive in this respect as may be noticed if an isolated tree is observed while emerging from the wintering condition. The side of the tree which received only the early morning sun is the first to become leafy and bear flowers. The south side is always considerably later.

(3) *Preparing the Bud-patch*—

A suitable bud is chosen and cut away in a direction from the upper side of the bud downwards towards the base of the budwood stick. The cut should be started at least 1¼ ins. above the bud and continued downwards for at least this distance below the scar. When this has been reached the bud, attached to its chip of wood, can be detached with a square cut across the bottom. From now onwards the greatest care must be exercised. The patch of bark is carefully loosened from the wood at the edges and then gradually peeled away.

If this operation has been performed successfully there will be a minute projecting peg behind the bud and a corresponding hole in the wood opposite.

The next sequence of events is carried out with an eye on the panel of the stock where the patch is to be placed. The sides are rapidly trimmed until the patch is about ⅛ in. less in width than the panel and when this has been done the top is cut off straight to make the patch rectangular. The patch when finished should be at least 2 ins. in length, for it is general experience that with a large patch there is a better prospect of a "take." It is then best to cut off one of the upper corners to mark which is the top of the patch and so avoid inserting it upside down. Buds put on upside down, when they grow out at all, only do so after some delay. At first they grow out downwards but, later, the young shoots gradually curve upwards producing an ugly S-shaped curved effect which persists for some months. Such buddings, when in the nursery, should be rejected for planting out; in the field they can, if required, be kept.

(4) *Insertion of the Bud-patch*—

In this stage the flap of bark covering the panel on the stock is stripped downwards until a length of wood equal to the length of the patch is exposed. The two upper corners of the flap are first prised up by means of the tongue of the budding knife and the upper edge is gently lifted. It is then easy to take hold of this edge between the thumb of the right hand and the budding knife and gently pull it downwards until it can be seen that the bud-patch will just fit the exposed panel. While this is being done the patch is held between the thumb and fore-finger of the other hand and as soon as the flap has been pulled downward sufficiently it is gently inserted on the panel in such a manner as to rest in the angle between the flap and the wood of the panel. The latter must not be rubbed in any way nor touched with the hand or the delicate cells on the outside will be injured, making union difficult or impossible. Moreover, the most scrupulous cleanliness is essential throughout, no latex or dust being allowed to contaminate the contact surfaces of patch and stock. After a little practice the pulling back of the flap and insertion of the patch should be performed almost simultaneously and at the utmost occupy five seconds.

(5) *Binding the Bud—*

The binding is started below the budding with a firm round turn to fix the lower end of the binding strip tightly. The flap is then loosely held in position over the bud-patch with one hand while the binding is continued spirally upwards with about 3/16 in. to ¼ in. of overlap. The tension may be fairly strong at first but must be gradually relaxed so that little pressure comes on the middle of the bud-patch. When the top of the panel is reached the tension can be once more increased and a tight joint made with the concluding round turns. The back of the knife should then be used to smooth over the overlap except in front of the bud-patch where pressure must on no account be employed. When the binding is finished, a bunch of about half a dozen leaves should be cut from the stock and tied, with the stalks upward, just above the budding so that the leaves, hanging downwards, protect it from the direct rays of the sun. Old binding strips, which have already been used, come in very conveniently for this purpose.

(6) *Opening Up the Budding—*

The budding is left in the stage described above for a period of 14 days. Opening up may then be begun but, in any case, it should not be delayed longer than the twenty-first day as every extra day increases the risk of moisture penetrating the binding strip and causing the bud-patch to rot through the attack of fungi and bacteria.

Opening up consists of removing carefully the bandage and cutting off the flap of bark which originally covered the patch but which is now shrunken and dead. It is not possible to see at once with the eye whether the bud has "taken" but an indication is obtained if the patch is scratched lightly above the bud with the point of a knife. If the scratch shows the bark to be green inside, union has taken place, and, if the bud was a good one, it will begin to grow out as soon as the proper conditions are set up.

During the early stages of its growth the young bud and also the bud-patch need protection against drying out by the direct heating action of the sun. The leaf shade should therefore be renewed or, what is much better, removed and replaced by a split bamboo about 18 ins. long, sharpened to a point at one end and stuck in the ground about 1 in. from the stock. This will give full protection to the young shoot and, at the same time, assist in directing its growth towards the vertical. The bamboo shoot should be removed when the shoot begins to grow beyond the top.

Mann[46] has given some very instructive figures demonstrating clearly the reduction of failures after opening by maintaining efficient shading. After experiencing considerable losses, in cases where the shade of leaves only was employed and renewed after opening, he paid more attention to this factor in a second series of buddings. The leaf shade was made heavier and the flap of the patch was allowed to remain shielding the bud. As a further precaution the split bamboo already described was employed. The figures given in Table XXXI are very convincing. The losses after opening are given in the last column as a percentage of the initial successes.

In the Dutch East Indies it is a common practice to shade the young bud by means of a bottomless

TABLE XXXI.

Clone.	Shade.	No. of Buddings.	Per cent Success.		Per cent Losses after Opening.
			Initial.	Final.	
No. 1	Light or none.	348	91	70	23
	Heavy.	283	99	87	12
No. 2	Light or none.	266	57	48	17
	Heavy.	302	88	84	4

planting basket which is slipped over the stock and pegged to the ground.

(7) *Forcing Out the Bud—*

The young bud cannot grow out as long as the dominating influence of the terminal bud of the stock is exerted, for most of the growth energy is diverted to this point. The most practical measure is to remove the influence of this shoot and make the new bud itself a terminal bud by ringing the stock a short distance above the latter. This is done seven days after opening and consists of making a knife-edge cut round the stock 4 or 5 ins. above the bud-patch. This cut is made right down to the wood and a similar parallel cut is then put about an inch above it. If now a vertical cut is made from ring to ring it is a simple matter to peel off the strip of bark between.

After ringing, growth of the terminal portion of the shoot slacks off and in about a week's time the first green beginnings of growth from the bud of the patch will be noticed; for now the growth activity of the stock below the ring is for a time concentrated in this bud.

Buddings made in the nursery for subsequent planting out in the field should not, however, be ringed.

(8) *Cutting Back—*

If the budding is left to itself after ringing it will be found that, very shortly, growth of the young bud will slacken and finally cease while, at the same time, growth of the terminal shoot of the stock will begin again. This occurs when the healing process on the outside of the ring has gone far enough to permit the flow of water and foodstuffs to the upper portions of the stock to resume its normal rate and course. This can be delayed by breaking or cutting off the terminal shoot. The greater the portion removed the longer is this delay and the more active is the growth of the budding. To get the maximum amount of early growth the stock should be sawn through at the ring, that is, about 5 to 6 ins. above the bud-patch. The portion of the stock now left above the bud is commonly known as the "snag."

X.—After-Treatment of the Budding.

The after-treatment of the budding depends upon the object of the operation.

(*a*) *Pruning the Stock.*

If the budding is in a multiplication nursery or has been made in the field the after-treatment is much the same in both cases. As soon as the new shoot shows its tip above the top of the bamboo this should be removed. After this the stock should be sawn off at the ring leaving what is known as the "snag." As growth of the young budding proceeds the snag dies and, if left to itself, is finally shed like the snag of an ordinary stump. Its fall is hastened by decay and the activities of white ants and a crater is left behind which finally becomes filled in and covered by new callus tissue.

The practice in the Dutch East Indies is to allow the snag to rot and fall naturally. There is nothing to urge against this practice for the snag is completely cut off from the rest of the stock by a layer of wood cells, impervious to attack by wood-destroying fungi or white ants. In Malaya, on the other hand, the practice has become established of sawing off the snag when the budding is five or six months old. This makes for a neater job and a more rapid closing over of the wound surface but it also has the effect of increasing considerably the cost per acre.

(*b*) *Precautions against Breakages.*

In the field, before the snag is cut off, it can be employed temporarily in exposed areas in connection with precautions against wind damage. A simple method is to lash the young shoot loosely to the snag using a simple round turn on the shoot in order that this shall not be constricted as the shoot thickens. This precaution is only needed for the first two or three months. Many breakages occur through carelessness, especially in weeding, but the precautions in such cases are obvious.

(*c*) *Planting Out Budded Stumps.*

If the buddings are made in the nursery, for subsequent planting out, the above procedure is unsuitable. It should be realized at the outset that great care and suitable conditions are essential for such an operation which, ordinarily, should not be risked outside the normal planting season.

After the budding has been successfully accomplished the bud should not be allowed to grow out until the stock is safely established in its new quarters. Unless the stock is ringed or pruned the bud will remain dormant for months. The budding will be ready for planting out about two weeks after opening but a delay of a month or two is immaterial so that a start need not be made until planting conditions are likely to be favourable.

In planting out the stumps care must be taken not to cut them too short. The cut should be made at a height of at least 3 ft. 6 ins. from the bud-patch or higher if possible so long as it is not made in the young, green wood. Cutting back should be carried out in the nursery three or four days before the stumps are required and on the following day the cut ends should be tarred. When the stumps are lifted the roots should not be drastically pruned but all broken ends should be trimmed and the cut ends tarred. Planting should be done in good top soil and the addition of a little well-rotted cattle manure made where available. Care should be taken to plant the stumps so that the bud-patch faces north and the split bamboo shades should be placed in position as soon as the holes are filled in. Wherever possible the stumps should be watered. They should then be allowed to settle down until the first shoots from the uppermost buds of the stump begin to shoot. This is a sign that the root has recovered from the shock of transplanting and begun to function normally again. At this stage the top shoots should be removed and the stump ringed and pruned as already described.

For planting out during the season after budding in the nursery, the stocks are ringed and pruned as when budding in the field. The buddings can be planted out when they have made several storeys of growth if the bud-shoot is cut back and the cut end dipped in melted budding wax. The cut must be made in the brown wood but as near to the apex as possible.

In all planting operations where buddings are involved, drying out is the greatest enemy. Consequently, not only must the stock be as tall as possible but efforts should be made to prevent drying out from the cut end and also to counteract the drying out tendency of the heated soil. Watering, the use of good dark soil, and covering the base of the stump with a mulch of grass or cover-crop weedings, are measures which suggest themselves for this purpose.

XI.—The Care of Established Buddings.

During the first two years a field of buddings should be patrolled at frequent, regular intervals. In the early stages there are several points to watch. After ringing, and before cutting back, extraneous shoots often develop on the stock. These should be removed as early as possible.

Occasionally two shoots may grow out of the bud-patch itself and as soon as one grows ahead of the other the weaker one should be carefully trimmed off.

Moreover, buddings frequently show a tendency to branch early at a low level and a strict watch should be kept on trees which do this. The side branches which make their appearance below a height of 8 ft. should be removed as soon as they are detected. This applies with special force to branches which appear up to 6 ft. for these may be on the future tapping surface. If allowed to grow too large they will not only distort the trunk but leave large scars when finally removed. Above this height it may occasionally pay, e.g., when the buddings have been made from expensive, high-grade budwood, to leave one or two low side branches until they are old enough to furnish material for further budding but great care should be taken to remove them neatly as early as possible.

XII.—The Best Time for Budding.

Statements as to the best time for budding are generally only partially correct for many factors may affect the success of a given operation. Mann has shown, for example, how largely success may be affected by the skill of the operator, the quality of the budwood, the condition of the stocks and the composition of the soil.[46]

Again, budding in the nursery can often be undertaken when budding in the field is hazardous. Even the statement that budding is inadvisable during wet weather needs qualification for the same investigator has shown that showery weather can be quite suitable for the operation. It goes without saying, however, that this should not be carried out while it is actually raining.

Certain definite guiding principles can, nevertheless, be laid down. So long as the stocks are in an active state of growth they are suitable for budding on to. Similarly, if an adult tree is actively "flushing" it will be suitable for taking budwood from. Outside the actual wintering season this condition may be present during dry weather for it depends largely upon the inherent periodicity of the tree. That is to say, the condition of the budwood and stocks may at times be suitable even in the dry season and, provided that adequate precautions are taken, budding can be carried out in the nursery. Should there by any risk of drought, however, budding in the field would be inadvisable.

Buddings from adult mother trees should not be attempted until preliminary tests have shown that the bark will strip easily.

It is impossible to lay down hard and fast rules as to the best time of day for budding. On cool cloudy days it is possible to work all day but, as a general rule, the morning hours between 6 and 9 and the afternoon hours between 3 and 6 make the most suitable periods. Every effort to keep down the cost per acre should be made and one possibility is to secure at least 120 buddings per man per day which will result in at least 90% of successes on opening.

XIII.—Labelling and Records.

The importance of accurate labelling and recording can not be over-emphasized. The slightest flaw in the pedigree of high-yielding plant material renders it not only valueless but dangerous. Buyers are entitled to demand stringent guarantees of the material supplied and these cannot be given unless accurate records have been kept.

(*a*) *In the Field.*

Before being issued to the coolie every stick of budwood should have the clone number marked legibly with pencil on the butt-end. Knowing the scheme of planting this number should frequently be checked on the work by the assistant in charge.

Previously to the work being started an adequate number of labels, one for each budding, should be prepared. These are best made of thin sheet galvanized iron, about 2 ins. square, with a small hole through which a wire about 18 ins. long is passed. On a label of this size there is space enough for both the clone number and the number of the individual tree if required. The letters and figures should be punched on the label, not painted. As soon as a budding is finished the coolie takes a label and bends the two ends of the wire together round the stock. The label is then allowed to lie on the ground. It goes without saying that, if any weeding is carried out while the buddings are young, due care must be taken to see that the wires are not cut through.

Square planting is always advisable when the budding of an area is contemplated, for, when a number of clones are being budded from, it is a simple matter to mix these systematically by putting them in order along the diagonals. To complete the operation white posts on which the clone numbers are painted should be placed along one side of the planting in front of the diagonals. It adds to the value of these indicator posts if their tops are painted with a coloured band, a separate colour being employed for each clone.

In the record book a chart of the area should be sketched, the trees of the different clones being indicated by special signs. To make this quite "fool-proof" a large stone—preferably of distinctive shape—should be firmly fixed in one corner of the field as a reference point and its position marked accurately on the chart. It should be borne in mind that endless confusion may occur before the trees are old enough to tap through changes of personnel, casualties to the trees, supplying of vacancies and other causes if these precautions are not taken.

When the trees are old enough, the clone number should be stencilled on the bark—preferably in white. It is also advisable to give each tree a serial number.

Recently, Cramer has published details of a method for avoiding irregular practices on the part of budding coolies who, in order to procure a greater percentage of successes, might use budwood from another source than the one intended. For example, instead of the buds being taken from the wood supplied these might fraudulently be taken from vigorous seedlings growing in the same nursery. Such a substitution, if successful, could not be detected until the buddings were a year or two old. Cramer has therefore advocated the marking of the buds before cutting with coloured waterproof ink. When the budding is opened the identification mark still remains and the bud is thereby authenticated. Cramer also sees in this marking method a means whereby suppliers can furnish guaranteed, marked budwood and he has applied for protection of the method in Malaya.[47]

In the writer's opinion the dangers from impure budwood are greatly over-estimated. At the present time it is possible to obtain budwood from the best clones from sources which have been controlled by research stations and the estates profit very largely from the sales. There is no reason to anticipate either *mala fides* or fraud, the mere rumour of which would effectively put a stop to a lucrative business. At the same time, estates which supply budwood should realize the latter and, by rigid checking, efficient recording, and permanent labelling, maintain the purity of their nurseries.

As for malpractices on the part of the budding coolies efficient supervision should make these almost impossible. Naturally, an undertaking which gives out a contract for a large budding programme to gangs of unsupervised coolies ought not to be surprised if such occur.

(*b*) *In the Nursery.*

When budding from a number of different clones the main nursery plots should be divided into convenient blocks, with a special identification post for each. A chart of these should be placed in the record book and, again, a boundary stone should be fixed at one corner.

There should be no mistake about the blocks being separate; distinct avenues, formed by pulling some of the seedlings, should be placed between them and, during the budding, the principle should be followed of keeping one coolie to one clone and one block until this is completed.

Before beginning budding, the nursery beds should be subjected to periodical thinning out until the remaining seedlings are spaced at least 1 ft. by 1 ft. If these intervals can be increased without undue waste of seedlings so much the better.

When the stumps are transplanted to the field the method of labelling and recording described in the preceding section should be followed.

XIV.—Budding in the Nursery or in the Field?

The decision as to whether it is better to bud in the nursery or in the field must be made in each individual case for much depends upon the date at which it is decided to bud the area and the amount of notice available.

The following general principles must be borne in mind when arriving at the decision. When seedlings are budded in the field the conditions are more strenuous and trying than in nursery budding. The more comfortable and quiet the conditions are the greater is the prospect of success. Moreover, supervision is more difficult and, if several clones are being used, mistakes more easily occur owing to the coolies getting out of line along the diagonals. The supply of budwood to the coolies also needs constant vigilance to prevent this going astray.

In the nursery supervision is easier while, owing to the shading effect of the other seedlings, conditions are better both for the coolie and the budding. Losses after opening are much less than in the field where a spell of unforeseen dry weather immediately after opening may reduce the percentage of success very considerably. It may then be necessary to do one or two extensive rounds of re-budding, making the operation long drawn out and the final stand of budded trees irregular in growth and size.

In passing it should be mentioned that budding by contract should not, as a rule, be undertaken in the nursery on account of the opportunities available for malpractices.

In field budding there is the advantage that the original root system of the stock is not disturbed nor does the budding receive the shocks involved in the planting of budded stumps. On this account alone field budding should be preferred whenever possible to nursery budding. Rebudding of failures may be required but, with carefully chosen conditions and adequate supervision, not more than two rounds should be necessary. Furthermore, it is always possible to bud a small reserve in the nursery to permit of supplies where required.

Difficulties may arise when only alternate plants are budded, but this subject is dealt with in a later section.

Budding in the nursery must be begun about five weeks before the time for planting. Care should be taken not to delay the start or prolong the operations unduly otherwise, if planted out near the end of the season, the young buddings may be exposed to drought conditions before they are well established.

One advantage of nursery budding is that, before an area is cleared, nurseries may be laid down six or seven months earlier in readiness so that the stumps are available when the planting season arrives. This method gives a year's start over planting seed at stake and budding subsequently in the field.

It should be realized that the planting out of budded stumps is an operation requiring the most suitable conditions and the utmost care but if the instructions previously given are followed there is no reason why it should not be successful.

The commonest practice in the Dutch East Indies is to bud in the nursery and plant out in the field.

The nurseries should not be placed actually in the field which is to be budded but as near to it otherwise as possible. The work of transporting the young budded stumps by hand is then not very considerable for a coolie can easily carry a bundle of four or five in each hand by the roots with the young buds pointing outwards and downwards to avoid damage. Every bundle should be taken directly to the assistant in charge of the work who should check the labelling and direct the consignment to the conductor who is supervising the planting of that particular clone.

For longer distances it may be found convenient to employ a stretcher so long as care is taken not to injure the stumps.

XV.—Multiplication Nurseries.

A multiplication nursery can be started from an ordinary nursery of seedlings provided that the latter have been thinned out early. The remaining seedlings should be left in regular rows at a distance of 18 ins. from one another. In the first place all seedlings should be budded and the first crop of budwood may then be expected 10 to 13 months later.

After the first cutting alternate buddings should be removed and, if required, used as stumps either for planting out in the field or in starting a new nursery; the stocks remaining in the nursery will then be at least 3 ft. apart, which distance may be retained permanently for the multiplication nursery.

In taking the first collection of budwood the cut should be made about 9 ins. above the union and 2 or 3 ins. above a group of bud scars. (In the case of the buddings which are to be removed, however, the cut should not be made lower than 18 ins. from the union and the stumps should be removed about three days later).

Confining attention to the permanent plants, the cut end should be tarred and the sprouting of the buds from below the cut awaited. If more than two buds shoot the two most vigorous should be selected and the remainder rubbed off as early as possible. At the end of the next season the plant will, of course, be Y-shaped and approximately double the quantity of budwood will be available. The two side shoots are cut back as before to a group of bud-scars and, for the third season, a pair of new shoots can be allowed to come on from each.

In succeeding seasons not more than four shoots should be allowed to grow from one stump and the plot should receive an annual dressing with a nitrogenous fertilizer.

Side branching of the shoots should not be allowed and should be dealt with as soon as noticed.

XVI.—THE TRAINING OF LABOUR.

The general experience in Malaya is that Chinese are much superior to all other forms of labour. Probably Javanese come next but frequently, with patience, Tamils, both men and boys, can be trained to become quite as expert. Chinese appear to need only to see the operation performed to be able and willing to try their hands straight away; Tamils need to be carefully instructed step by step.

When training a gang, more coolies should be selected than are actually required. They should be taken to an old nursery, taught first of all to cut a panel, then to prepare a bud-patch and so on. It is not too much to allow one day for instruction in each step. Finally, each should be allowed to make half a dozen buddings on two or three successive days. At the end of 14 days these should be opened and tested by the same person and the weaker members of the gang weeded out on a basis of the results.

It is almost always a waste of time to try to train women.

Throughout the instruction the coolies should have the importance of labelling driven home to them.

Experience has shown that the system of budding by contract is open to objection on account of the difficulty of supervision and the opportunities it affords for fraud. The system of paying a bonus for every "take" suffers from the disadvantage of increasing the labour costs of the operation which ought not to exceed two dollar cents per bud. A bonus would be more reasonably based on the percentage of successes and not on the actual number. Compare, for example, the case where a man makes 100 buddings in one day, obtaining 95 successes, with the case in which a second man makes 150 buddings in the same time and obtains 110 successes.

XVII.—The Cost of Budding.

In estimating the quantities of material required the following items may be found of assistance:

(*a*) 5 yds. of cloth are sufficient for 270 buddings.

(*b*) 1 lb. of "Entwas" is sufficient for 150 buddings.

(*c*) 1 yd. of budwood should furnish at least ten good buds.

(*d*) The knives, boxes, and labels for 50 acres should not cost more than 20 Straits dollars for five coolies.

(*e*) At least 100 buddings per man per day should be expected and 90% of successes.

(*f*) One coolie should be able to open the buddings on two acres in one day and about the same time is required to ring the same number. Cutting back requires approximately double this time.

(*g*) The price of budwood should not exceed one Straits dollar per yard except for special material available in limited quantities.

XVIII.—The Packing and Storage of Budwood.

Plantation managers should possess a knowledge of the methods of packing and storing budwood for several reasons. The budwood they purchase may have to travel a considerable distance by road, rail or sea. On arrival it is necessary not only to check immediately the condition of the wood but, as it may not be possible to use it on that particular day, also to store it in conditions which will not affect it detrimentally.

During its journeying and subsequent storage the following must be guarded against:

1. Drying out of the bark.

2. Chafing and rubbing of the bark and buds by packing materials.

3. Development of moulds or bacteria in these materials or on the budwood itself.

The subject of packing has been thoroughly studied by Maas[38] and the following is based upon his researches combined with observations made from time to time at the Rubber Research Institute of Malaya.

Theoretically, all budwood begins to deteriorate progressively from the moment it is cut but, practically, a good deal depends upon its age.

Apart from difficulties of manipulation, young green budwood deteriorates so rapidly that, if a normal number of "takes" is looked for, it is probably unsafe to use it later than the second day after cutting and then only if it has been kept standing in water. If green budwood of this kind is packed and sent away from the estate only a small percentage of successes can be expected however carefully it is packed; in fact, the number of good buds per yard decreases so rapidly that after three or four days it is not worth the trouble of using, except in the case of valuable material which it is desired to get into the multiplication nursery at all costs.

Young, partially green, budwood is much more satisfactory material. If, after cutting, the sticks are stored in a cool place with their lower ends in a tin containing water, and if the water is renewed twice daily, they should remain in a usable condition for a week. This kind of material does not, however, stand transporting for long distances, even if carefully packed, and as a rule should not be sent such a distance as will prevent its being used on the fourth day at the latest.

The green surface of young budwood, not yet having obtained its protective covering of brown cork, readily allows moisture to escape from the cells of the cortex. It is in order to make good this loss that the sticks are stored with their lower ends in water so that the ascending stream of water in the wood may be kept going. The object of any packing method is to surround the sticks with a layer of moist material which will remain so for days and thus check the loss from the green surface.

Older, brown budwood does not lose moisture from the bark so readily and may be kept in water for nine or ten days and, as distinct from the case with green wood, if loss of moisture from the ends is prevented it can be kept in good condition for the same length of time by a suitable method of packing for transport.

The packing methods which have been tried out with successful results are the following:

(*a*) For sending budwood for short journeys by road, rail or sea involving not more than three days.

1. The budwood is cut into metre lengths which are sent directly to the packing shed where they are placed vertically with their lower ends in water to await their turn for being packed. When this arrives the two ends are wiped and about ⅛ in. trimmed from each with a sharp knife. The ends are then dipped into melted budding wax, after which the sticks are tied tightly together in bundles of five or six which are wrapped

round with plantain leaf-sheaths in such a way that the ends also are completely closed in. When this is done a second binding is placed round the bundle. From six to ten of these bundles are then placed in a strong wooden box, the bundles being tied together, and the space between them and the sides of the box filled with dry sawdust. It is an additional protection to roll the bundles in sacking before placing them in the box.

The budwood should fit tightly in the box, for, if the latter receives much handling during the journey, there is a possibility of buds being damaged through the rubbing of the sticks upon one another.

2. The sticks are treated and bundled in the manner described above but instead of dry sawdust being used as a filling, coconut fibre which has been slightly moistened beforehand, is used. Where large quantities of budwood are being dealt with the economic advantages of coconut fibre are apparent.

(*b*) For longer distances, involving a journey of about seven days, the following method is useful. A length of damp sacking is placed flat on the floor and the sticks rolled in this singly so that each is covered by a layer of sacking. When as many sticks as possible have been rolled the bundle thus formed is bound tightly with cord. The bundles may then be placed in the box and damp powdered charcoal filled in as packing.

A very thorough test of methods of packing budwood was made by Billington in 1928.[41] Consignments of both green and brown wood were forwarded from Sumatra to Kuala Lumpur packed in bundles into boxes by three different methods:

(1) The stocks were packed in layers of coconut fibre.

(2) Bundles of five sticks were packed in banana leaf sheaths and packed in dry sawdust.

(3) The sticks were wrapped in dry sacking and packed in slightly damp charcoal.

Four of the best Avros clones were represented, viz., 49, 50, 80 and 163, and the value of the test was greatly increased by employing three estate coolies and two experienced conductors, all of whom made buddings from both kinds of wood from all four clones.

The duration of the journey from estate to estate was about three days and for this period all three methods proved efficient for both green and brown wood. The sole difference that appeared at all significant was in the case of the sacking and charcoal packing. This was considered to have kept the bark in a more pliable and tractable condition. It was also noticed that the coconut fibre did not keep the sticks from rubbing against the sides of the box.

The average success obtained for the brown wood is shown in Table XXXII and for the green in Table XXXIII.

TABLE XXXII.

Clone	Percentage of Success (Brown)		
	Charcoal	Banana	Fibre
49	63	93	98
50	96	93	94
80	87	96	88
163	93	89	93

TABLE XXXIII.

Clone	Percentage of Success (Green)		
	Charcoal	Banana	Fibre
49	68	78	80
50	94	100	95
80	81	89	79
163	78	87	77

It is to be hoped that a similar set of experiments will be carried out where the journey involved has been of longer duration. In this way it should eventually be possible to standardise packing methods suitable for definite periods of time and having due regard to expense.

In all cases the budwood should be unpacked and washed immediately on arrival. The lower waxed surface should be trimmed off with a sharp knife and the sticks placed vertically with their lower ends in water. They may then be left standing in a cool situation until required.

It is not generally realised how hardy mature budwood really is when properly treated. The blame for non-success is frequently placed, quite wrongly, on the budwood and no effort is made to check the technique which is much more likely to be responsible. Mature budwood can be kept safely for ten days and still give a reasonable percentage of "takes" per metre.

Mr. R. O. Jenkins of Prang Besar Estate kindly furnished the author with particulars of a case in which the budwood was packed in charcoal by the ordinary method and shipped to an estate in Brunei, Borneo. Although the journey occupied eight days

23% of successes were secured in ordinary estate budding.

Before attempting to export budwood packed in coconut fibre or plantain sheaths inquiries should be made as to whether the Plant Pest Ordinances of the importing country forbid the introduction of such material.

XIX.—Test Tapping of Buddings.

Test tapping should be carefully distinguished from commercial tapping. The object of the former is to gain some idea of the relative value of the trees and should be started at as early an age as possible. Buddings can be test tapped at three to three and a half years from the date of budding in a manner which will give a clear indication of their yielding value and at the same time impose no undue strain on the tree. These tappings should be regarded only from the comparative point of view for, in unproved clones, it is not possible to get an idea of commercial value before they have been tapped regularly for three or four years. The rate of increase of yield with time is all important and records for three or four years are needed before it can be seen how the yield curve is going.

It is for this reason that a tapping test should be carried out continuously and not be confined to a few tappings either scattered throughout the year or concentrated in a short period. During 1928 the Pilmoor clones were tapped alternate daily in alternate months. This test, therefore, was not on commercial lines but it showed conclusively three main results.

In the first place the clones which started well continued so. Secondly, none of the poorest clones showed any noteworthy promise of improvement while thirdly certain clones which started together on a low or medium yield level separated themselves out from one another as the test proceeded. Those which were really poor remained poor while those which were merely slow starters showed a satisfactory rate of increase. Final conclusions as to poor clones cannot therefore be drawn until the second year of tapping.

Whether the test is a preliminary one of young buddings or a commercial test of older trees the only satisfactory method is one which will give the daily yield of dry rubber per tree.

The latex should be coagulated in the cup and when a number of biscuits have accumulated on each tree these should be creped, dried and weighed. Reliance should not be placed on latex volume measurements alone but if both volume of latex and weight of dry rubber can be measured it adds to the value of the test. The caoutchouc content is generally very high during the first few tappings of each month but gradually reaches normal during the second half of the month.

If the acreage is large and the available labour scanty the situation can be met by selecting at least 20 trees of a clone by chance and bulking the latex from these each day. This should be coagulated separately and the lump made into sheet or crepe which should be dried for a week and then weighed in order to get the average per tree.

In the majority of tapping tests outside Java the cut has been a half spiral opened at a height of 20 ins. from the union. In Java, on the other hand, the cut is usually only over one-third of the circumference. The half cut is to be preferred as the third has a tendency to produce triangularity of the trunk.

Much more research work is needed before we know the best way to tap. Indeed, there are indications that all clones should not necessarily be tapped by the same method. It is unfortunate that monthly yield curves, such as those employed by

Heusser[22] for clones 51, 71, 152, and 163, are only available in a few cases and then only for young trees. In the case of buddings less than six years of age experience in Malaya has confirmed and amplified results obtained in Sumatra. There is now evidence of three types of yield curve given by the monthly results. In certain clones the yield rises rapidly during the first days of tapping to a maximum on or about the fifth day. The yield remains at this high level for four or five days and then falls gradually to a uniform level by the time the second half of the month is reached. In the second type the yield curve closely resembles that given by seedlings, that is, the yield rises gradually during the first ten days or so of tapping to remain constant for the rest of the month. Clones of the first type furnish better results if tapped daily in alternate months while clones of the second type are better if tapped continuously alternate daily. There is a third, intermediate type of slow starting clones for which, probably, again daily tapping in alternate months would give slightly better results than alternate daily tapping.

XX.—Interplanting of Seedlings and Buddings.

This subject is probably the most debatable one in connection with the budding of large areas.

The practice of interplanting dates from the early days of budding when it was realized that, although the superiority of proved budded stock had been proved experimentally, a certain amount of caution was necessary until it had been satisfactorily shown that buddings had maintained this superiority in the conditions and subject to the established routine of the plantation. Prominent workers such as Heusser and de Vries advocated the practice.

Furthermore, various alarmist rumours had gained credence amongst planters as to the strength, liability to disease, and quality of bark of budded trees, and it was necessary to await the results of definite experimentation on these points before it was possible to speak on them with confidence.

But with the great strides made since 1926 the position has radically changed and as a result there remains no argument for interplanting.

Nevertheless, it is recognized that some time will be necessary before it is possible to convince the industry that this is the case and, as interplanting will therefore continue, some discussion of its difficulties seems called for.

When two types of tree, differing largely in growth and habit, are planted closely together in the same area, the question of possible competition between the individuals of both types at once arises. The factor which has been most discussed is that of overshading for it has been generally feared that, in the second and third years, the seedlings would have progressed so much more than the buddings that the growth of the latter would be seriously interfered with.

It is obvious that the original planting distance is an important factor. The closer they are planted the greater is the liability of the trees to interfere with one another but with plantings of less than 140 to the acre the risk should be small indeed.

But the whole question of planting distances bristles with difficulties and much more experience and experimental work are required before anyone is in a position to advocate a solution. Again, it is becoming more evident every day that very shortly the advice to interplant buddings and seedlings will become obsolete which will happen as soon as tapping on the renewed panel of bark has demonstrated certain clones to be satisfactory in this respect. When this has been proved there will be no necessity for interplanting and any experimental work based upon it will be out of date.

Leaving out of discussion for the time being the question of planting distance, the main problem in interplanting is to secure uniform development throughout of both seedlings and buddings. One method advocated is to plant the seedlings intended to be budded one year before the others. The disadvantages of this method are obvious. A vigorous budding on a 12 months' old stock often makes about 6 ft. of growth in the first six months so that it is quite possible that the buddings will overshadow the seedlings, more especially as they will branch earlier. This tendency to overshadow can be corrected to some extent by (1) budding as late in the season as practicable so that the seedlings may get two or three months' start or (2) planting vigorous basket plants instead of seed about the same time as the budding is carried out.

There is a certain amount of risk involved with both these methods, so far as evenness of progress is concerned, and there is the additional disadvantage of delay. It is better therefore to consider some alternative.

A second method is to plant the whole area with stumps, budded and unbudded, in which case it would seem advisable to plant out the budded stumps about a month before the unbudded. This would give the former time to recover and settle down so that they might be cut back shortly before the unbudded stumps. The disadvantage here is the possibility of a large casualty list unless the weather conditions are just right. This means that a good reserve of stumps of both kinds must be maintained in the nurseries until the success of the planting is assured.

The third method is to plant up the whole area with seed and bud the alternate plants on the following season. In this case if the buddings are cut back the seedlings will be left with a big advantage, so far as extension growth is concerned and this inequality must be corrected by some method of pruning. Before doing so due regard must be paid to the following considerations. The pruning cut must be made well above the future tapping surface. Secondly, if an established seedling is cut back the growth response will be much more rapid and vigorous than with an ordinary transplanted stump. This will be very marked if the cut is made at the beginning of the rainy season. Lastly, it should not be expected that all the seedlings will respond alike to the pruning stimulus—every plant must be regarded as a special case.

Bearing these considerations in mind, both seedlings and buddings should be left until the latter are about six months old. The seedlings can then be cut back to about 5 ft. from the ground, provided that the cut can be made in ripe wood a few inches above a group of buds. No closer guide can be given. A definite pruning height must not be rigidly adhered to but the assistant in charge should inspect each seedling and mark those which need pruning 1 in. above where the cut should be made. Long shears can be used with advantage to speed up this pruning work.

Only one bud should be allowed to grow as a leader; any others which break out from behind the pruning cut should be thumbed off as early as possible.

If interplanting is carried out an endeavour should be made to reduce the number of buddings made to that required in the final stand plus a small margin for casualties. All buddings above this number represent loss of time and money. This being the case it is inadvisable to plant more than 120 buddings and seedlings to the acre. A planting distance of 20 ft. by 18 ft. is very suitable especially if combined with the arrangement of buddings and seedlings shown below:

B	S	B	S	B	S	B	S	B	. . . . .
B	S	B	S	B	S	B	S	B	. . . . .
S	B	S	B	S	B	S	B	S	. . . . .
B	S	B	S	B	S	B	S	B	. . . . .
B	S	B	S	B	S	B	S	B	. . . . .
S	B	S	B	S	B	S	B	S	. . . . .

It should be borne in mind that the tapping test can be begun when the buddings are in their fourth year so that it should be possible to pass judgment upon the buddings earlier than on the seedlings. But if the planting distance is too small the crowding of the trees will retard the buddings to such an extent that this early test will not be possible owing to their lack of sufficient girth and consequently the object of the budding operation will be largely if not wholly frustrated. There are now so many proved high-yielding clones that there is no reason for employing doubtful ones. Moreover, the number of the former will increase yearly as also will the supply of budwood so that when once the buddings can be regarded as established and thriving, it becomes merely a question of deciding which of the seedlings come most nearly up to their standard of yield, leaving the remainder to be thinned out when they begin to crowd those intended to form the final stand.

XXI.—Mixing Clones.

The research institutes of the Dutch East Indies are unanimous in recommending that about six clones should be mixed equally in any new planting. On the other hand, Cramer is an advocate of the block system of planting—one clone to one block. The author is himself in favour of the block system but does not regard the question as finally closed.

A discussion of the two opposing views may therefore be of interest.

Mixing of clones entails complications in the organization of supply, labour, labelling and recording, with a corresponding increase in the amount of supervision required. This all adds to the initial difficulties—often of an inexperienced staff—and also to the cost of the operation. When the area finally comes into tapping each task will contain trees of widely divergent character and, should it be intended to compare clone yields, this work will be complicated and difficult in practice. Futhermore, it is very unlikely that all the clones will be ready for tapping at the same time, which will add a further complication.

As against these arguments one may advance the opinion that, if the clone yields are not uniform, mixing will tend to equalize yield throughout the area. Further, if any of the clones fail the loss will be spread throughout the area.

But the prospect of a clone being of no value is so remote that it robs arguments of this kind of most of their value and strengthens the case for block planting. The actual size of the block must depend on the area to be planted and the number of clones it is desired to employ. In a small area it may consist merely of two or three rows but in larger operations five acres should be a minimum.

XXII.—The Future of Budding.

(a) *General.*

It is often argued that budding is only a temporary measure in yield improvement and that methods of seed selection will be developed at a sufficient rate to make it obsolescent at an early date.

Nothing could be further from probability. The budding method has not yet been developed to meet a tithe of the demands that the planter may make of it while prospects of yield improvement by methods of seed selection are still remote.

It is important to remember that there is no evidence against the existence in Malaya and Ceylon of clones yielding far more highly than those which are regarded to-day as first class. It would be a great mistake therefore not to prosecute energetically the search for such clones in these countries.

A systematic examination is called for of all remaining high-yielding trees of the first and second generations of those originally introduced to the East, for the evidence all points towards the first generation trees including some very high-yielding types and it is regrettable that so many have been allowed to disappear.

Moreover, in the general plantation population there is also a possibility that careful search may detect mother trees capable of originating even better clones than the present best and efforts should not be relaxed until this point has been settled.

There is obviously a limit to what can be accomplished by budding which is set by the fact that, so far as we know at present, a budding is a repetition of and not an improvement on the mother tree. But it should be remembered that it has not yet been possible to make any comparison of the yielding capacities of mother tree and progeny. Data for such comparisons will shortly be available, for the mother trees of some of the A.V.R.O.S. clones were only 8 to 11 years old when the first buddings from them were made by Heusser.[6] Within two or three years, therefore, it should be possible to estimate whether, age for age, these buddings are as good as their respective mother trees. Should they prove actually to be better it will be necessary to revise several current conceptions of the nature of buddings.

Naturally, the question will be complicated by the different tapping systems employed. Generally the older mother trees had been tapped daily for lengthy periods and the incidence of Brown Bast was frequent. On the other hand, buddings have been tapped conservatively for, as a rule, investigators have been anxious not to overtap the young trees and have been satisfied with an indication of their quality.

It seems very improbable therefore that we shall ever obtain exact numerical comparisons either between mother tree and clone or clone and clone. Yield figures will certainly be obtained, but these will vary widely for the same clone in different environments and will not be easily comparable with one another. Indeed, there seems small prospect of our improving on the present position with regard to the valuation of a clone. The preliminary estimate and recommendation will still need to be the result of patient experimental work by the research worker while the final valuation will be made in the field by the planter after estimating the improvement in yield of his fields obtained by employing this particular clone.

Only in one direction will the planting of clones on a large scale for comparative purposes assist the research worker. Owing to their small variability the trees of a clone form very suitable material for tapping trials and, by employing buddings for this purpose, it should be possible to resolve many of the outstanding problems connected with tapping. But before this can be done much more experimental work is needed to determine the most suitable tapping method for each clone. A straightforward comparison of clones A, B, and C, all tapped in the same manner, is of very little assistance if it is found later that each has its own optimum tapping system and period.

And, so far, all the evidence available points in the direction of this being the case.

(*b*) *Reconditioning of Old Areas.*

Within very few years this problem will become one of the most pressing in the rubber-growing industry and it is somewhat surprising to find how little this is appreciated throughout the East. Thus we have to-day the paradoxical situation in which planting opinion is convinced that the effective life of a rubber tree is from 30 to 35 years and yet carefully refrains from discussing the measures to be taken, in view of this, in order to recondition the plantations.

No doubt the problem has failed to secure consideration by planting companies in Malaya owing to the alternative policies of amortization and the replacement of all non-paying areas by new extensions. The first alternative is of little benefit to the industry as a whole while the second is already almost non-operative in Ceylon and Java and will eventually become the same in Malaya and Sumatra.

The ideal method would be one which would maintain the old area in a paying condition throughout the reconditioning process. The exact method will need to be worked out carefully experimentally but will probably develop on lines like the following, modified according to experience and local conditions.

A year or two before the start, a few of the highest yielders, six to nine, scattered throughout each acre, will be marked for retention and rested while the remainder will then be tapped to death. The latter will then be cut out and the smaller group be brought into normal tapping. Thorough cultivation, manuring and establishment of a cover will follow and nursery buddings brought in immediately this is completed. The benefit of the soil treatment will be experienced by both young and old trees alike. Normal tapping of the latter will be possible during the next three years at the end of which the yield per acre may be supplemented by light tapping of the buddings.

A second resource would be to take the worn out area and tap the whole to the fullest possible extent for two years by putting two cuts on each tree and, where feasible, tapping twice daily.

By the end of the second year the extra crop so obtained would allow the estate to contemplate the cutting out of the area. This would then need to be cleared, cultivated and manured and then planted up with buddings. At the end of four years the area would once again be in tapping.

(*c*) *Budding and Seed Selection.*

In the past a good deal of patient research work has been expended in an endeavour to determine the factors responsible for yield in Hevea. Unfortunately the results have been meagre when considered from the point of view of estate practice and the research worker is still not in a position to say why certain trees yield much more than the average while others show contrary behaviour.

Research has now become definitely directed towards seed selection and breeding, the latter of which entails the use of methods of self- and cross-pollination.

Owing to the inaccessibility of the inflorescences on an adult seedling tree, say 10 to 12 years old, it is almost impossible to carry out successful self- or cross-pollinations. Furthermore, although the question cannot be regarded as finally settled, it appears as though many trees are normally self sterile. Heusser has shown, however, that although a mother tree may be self sterile buddings made from it may be fertile amongst themselves. Should this be generally true two serious obstacles to experimentation will be removed.

Again, the undoubted early flowering of buddings will enable results to be obtained earlier than would be possible with seedlings.

When hand pollination is required buddings will furnish large numbers of easily accessible inflorescences until the trees are five or six years old, especially if light staging is erected round those under observation. Moreover labelling, recording and inspection will be rendered correspondingly easier.

Again, it is almost certain that when a successful cross is made only a few seeds of this will be available at first. If the resulting seedlings are fertile with respect to one another and are planted out in an isolation seed garden by themselves, it will still be some years before an appreciable quantity of seed is produced. On the other hand, if only three seedlings were produced in the first instance, and were used progressively for budding into a multiplication nursery, no less than 11,000 buds could be available at the end of the third year. Assuming that the first crop of seeds from the seedlings were produced in the fifth year and gave 1,000 seedlings, we have to set against this the fact that in an equal period over 1,000,000 buddings could have been provided from the multiplication nursery. These figures should be sufficient to convince anyone of the fact that, for many years, efforts at seed selection will need to be supplemented by budding methods.

Budding will be essential for the establishment of isolated seed gardens but it is often mistakenly assumed that if buddings from a single mother tree are planted in such a garden the resulting crop of seed will have the special high-yielding properties of the original mother tree.

This is not the case: the assumption is based on a false analogy with cereal plants which are normally self-fertilized. To start a Pure Line of high-yielding Heveas two requirements are essential: first, a parent which is genetically pure with respect to the character for high yield, and secondly, self-fertilization of the mother tree or cross-fertilization of buddings taken from it. The second requirement can now be easily satisfied but we are far from being able to satisfy the first. Our knowledge of the heritability of yield is almost nil and it is essential that this consideration be borne in mind if waste of effort and enthusiasm is to be avoided.

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CHAPTER II

SEED SELECTION AND BREEDING

I.—Introduction

The history of the introduction of Hevea brasiliensis to the East is well known. In the earliest days of rubber planting recourse had necessarily to be made to the nearest supplies of seed, which explains why Ceylon and Malaya formed the sources of supply for the developing rubber-growing countries of the East.

Owing to the restricted nature of the first imports of seedlings from Kew to Ceylon and Malaya, the situation developed in which the entire plantation population of the East had arisen from seed which was the result of free inter-crossing of plants which were descendants of the few original trees.

In spite of the pages which have been written on the history of the introduction this is not clear in detail, but, so far as Ceylon is concerned, the original Wickham seedlings were definitely responsible for the start there. From this original stock, but also from a second generation, seeds were obtained by pioneer Malayan estates and from the latter exported to Java and Sumatra.

But, in the case of Java, there were other lines of introduction. For example, two Wickham seedlings were received at the Cultuurtuin, Buitenzorg, in 1876. The two trees are still healthy and vigorous and capable of being tapped. A consignment of seed was also received in 1882 from the Consul-General of the Netherlands in Penang and from this 33 plants were successfully raised. Of these 22 have been cut out on account of low yield but the remainder still give 30 to 70 grms. of dry rubber per tapping. So far as can be ascertained, these trees are second generation material from the 22 original Wickham seedlings received at Singapore in 1876 and of which nine were planted in the garden of the Residency at Kuala Kangsar. From these two centres seed was distributed throughout Malaya.

These examples will serve to emphasize the fact that, although the present population of the plantations has descended from relatively few ancestors, it is the product of free intercrossing between parents of different generations which were by no means pure to begin with. The result is the existence of a vast number of different types, differing both in botanical character and productive capacity. Both are capable of being investigated but, up to the present, research has been unable to demonstrate any clear connection between them.

II.—The Nature of the Problem.

It has already been shown what can be accomplished by the method of budding and it will be useful at the outset to have before the mind a clear idea of what it is hoped to accomplish by methods of seed selection and breeding.

This may be described generally as a raising of the average plantation yield to one near that of the best trees which are known to exist and of which many estates possess examples. Good grounds for the possibility of this are held to be given by the great variability shown in a plantation population. But before attempting improvement by the long and laborious methods involved in seed selection and breeding it is customary to investigate whether the material to be improved is worth the trouble or whether results cannot be obtained more easily and quickly.

At one period the possibility was discussed of improving plantation stocks by the introduction of new material from South America. It was considered that Wickham might not have obtained his seeds from the best districts of Brazil and that an effort to explore the ground afresh might be worth while.

In 1913, Cramer visited Brazil for this purpose, and at the International Rubber Congress held at Batavia in 1914 he communicated some of the results of his investigations.(1) He found that the variation in wild trees was as great as in the cultivated ones; not only was yield a variable quantity but actual barren trees were encountered. He made studies of seed variation in different trees growing in the same spot and in trees growing in different districts. He was able to collect seed from trees in full bearing and in July, 1913, to establish a number of seedlings successfully at Buitenzorg. Although he found great differences in character and vigour of the different lots of seedlings he could not relate these to seed differences.

No superior planting material has resulted from this introduction.

Cramer advocated the introduction of new types from Brazil as he thought that efforts ought to be made to discover the "Ledgeriana" of Hevea. As a matter of fact two Java estates had previously imported such seed, Tarik Ngaroem in 1896 and Pasir Oetjing in 1898, but nothing useful resulted.(2) Most probably it was the latter import which gave rise to the famous canard anent "Black Hevea." As a further example there stands in the Buitenzorg Cultuurtuin a group of nine trees, the survivors of a batch of 47 raised from seed collected from one of the good trees in the experimental selection field at Surinam. They are all low yielders while the others have already been cut out on account of their poor character in this respect.

It appears therefore that, in point of fact, Wickham was really very fortunate in his collection of seed and that the prospect of improvement by the introduction of better is not encouraging. Moreover, the risk of introducing pests imposes a further practical barrier to the import of seeds from South America. The case for improvement by means of selection and breeding from the existing plantation trees is therefore all the stronger.

III.—Early Work on Seed Selection.

(*a*) *Selection of Illegitimate Seed.*

"Illegitimate" is the term applied by Dutch workers to seed in which the female parent is known and the male parent unknown. It is not a good term as, in the case of a self-fertile tree, it classifies together seeds produced by self-pollination with those due to cross-pollination.

Previous to 1920 the bulk of the work on the selection of seed from high-yielding mother trees had been carried out by planters in Java and the names of certain of these, e.g., Hamaker and Holle, are now household words in the domain of rubber research. The work had the sympathetic co-operation and assistance of the research stations but definite controlled scientific work was not carried out by the latter on this particular chapter.

In Malaya, progress was negligible. In 1915 Burkill described an attempt that was being made to mark down the best of the oldest Wickham trees in the Singapore Gardens which seemed likely to serve as parents for improved stock. He gave warning that the work of selection would be tedious and cover many years but, nevertheless, he considered that the work would prove worth all the time absorbed. He also anticipated experimental difficulties, for the trees had often been subjected to strange and different tapping methods in their early yield days.[3]

No further mention of this work exists and it evidently lapsed on the departure of Burkill from Singapore for his successor, on arrival, found only one tree remaining and this was cut out shortly afterwards on account of root disease. The enormous value of these trees from botanical, economic, and historical points of view was evidently never realized in Malaya.

In Ceylon the position is much better, for the Wickham trees have been safeguarded and kept under observation. Attention has become concentrated upon the now famous tree, Heneratgoda No. 2, on account of the high yields reported for it but the tree has also served as the starting point of interesting lines of research work. Furthermore, as buddings have been made from it, there is now no risk of any valuable characters of the tree being lost to Ceylon by the death of the ancestral type.

According to Petch[7] Tree No. 2 was tapped, with short intervals of rest, for four years and nine months, between December, 1908, and August, 1913. The total yield was 392 lb. 7 oz., but the tapping system was a full herringbone, with three V's at the start which were increased later to six. Moreover, in the first years the tapping was daily in alternate months while from November, 1912, it was daily and continuous.

Illegitimate seed was collected from this tree in

1911 and the year-old stumps from this planted out on the Peradeniya Experiment Station in 1912. Altogether 252 trees were planted 141 to the acre, but in June, 1916, after a cursory inspection, they were thinned out to 90 per acre leaving only 161 trees. From a scientific point of view this was an unfortunate mistake as the yields of the trees cut out are now unknown.

The remaining trees have been investigated by Bryce, Gadd, and Taylor during the years 1921-25 but the present purpose will be served by considering the results published by the last-named.[6] Two further publications are by Bryce and Gadd.[4][5] Except where otherwise stated the figures given are for the total yield per year.

The extent of variation in the residual population can be seen from the figures of Table 1, and although the variability was less than that of a plot of mixed trees this did not decrease as the tests proceeded.

TABLE 1.

Year	Highest Yielder		Lowest Yielder		Average
	Tree No.	Yield	Tree No.	Yield	
1921-22	67	8.1 lb.	116	3.0 lb.	4.9 lb.
1922-23	5	11.2 ,,	117	2.9 ,,	6.0 ,,
1923-24	5	10.8 ,,	117	2.5 ,,	5.1 ,,
1924-25	41	13.4 ,,	118	3.1 ,,	7.2 ,,

When the trees were 13 years old, therefore, the yield per acre was just under 650 lb.

Several interesting points are brought out by the figures for the individual trees, for these did not retain the same order of yield capacity from year to year. In 1922, for example, 11% of the trees yielded less than in the previous year while, in addition, six trees went dry during the year. The number of trees yielding at least 5 or 10 lb. per annum is given in Table 2 the third tapping year being very wet with a consequent loss of yield.

TABLE 2

Year.	Age of Trees.	No. of Trees giving	
		5 lb.	10 lb.
1921—22	10 yrs.	24	—
1922—23	11 „	98	6
1923—24	12 „	72	4
1924—25	13 „	139	19

It is apparent that a better result had been obtained than would have been given by an ordinary seed sample but this is by no means as good as might have been obtained by budding from proved clones. It is also possible to see that if a yield of 900 lb. per acre had been required at the age of 11 years it would have been necessary to select from more than 4,000 similar seedlings to obtain sufficient material to plant up one acre. It is obvious, therefore, that experiments such as the above constitute only the first step in selection work.

As an example of pioneer work of this kind in Java the work of Holle on Pasir Waringin Estate may be quoted.[8] This estate was originally planted from Vallambrosa seed.

Holle selected his mother trees by means of yield tests commenced in 1915. He judged the performance of a tree by the ratio of its yield to that of the average tree yield of the surrounding field. No tree which was not at least twice as good as the average was included in the register.

The seed of the remaining high-yielders was collected separately and sown in special nursery beds. If the growth in any bed showed a large number of different seedling types the mother tree was rejected as also was any tree which showed signs of disease.

Sixty-one mother tree nursery beds remained and the seedlings from these were planted out in daughter plots in 1916. The trees were brought into tapping when four years old and the daily production of each measured. At the end of six months the daughter trees were classified according to whether the average daily production was below 4 grms., above 8 grms., or between 4 and 8 grms. From these figures 25 mother trees were selected as good and of these, six were finally classified as superior. The progeny of the six contained few of the lowest class and a high proportion of the highest.

Holle's experiments showed that the large yield of a mother tree did not guarantee high yield in its offspring—a very important conclusion. Moreover, a good mother tree often had a large proportion of trees which were not tappable at the end of four years. These may have been good yielders but the delay of two or three years in bringing them into tapping was a serious disadvantage.

Similar experiments were carried out by Hamaker on Kiara Pajoeng Estate with his seven best mother trees.(2) He also found great variation in the mother trees, considered from the point of view of the heritability of their high-yielding character by the illegitimate progeny, but he agreed with Holle in concluding that better yields were to be expected than from an ordinary estate sample. For example, when the trees were ten years old the yield of the Pasir Waringin experimental area was about 750 lb. per acre.

De Vries and his colleagues also quote the instance of Pataroeman Estate which was planted exclusively with seed from the Kiara Pajoeng mother trees. When these trees were 11 years old the yield was 760 lb. per acre, which was estimated to be 65% greater than the normal yield of 430 lb.

In passing, reference may be made to the valuable publication of de Vries and colleagues referred to above.(2) It not only reviews completely the work in Java on the improvement of Hevea but forms an admirable summary of the scientific and practical aspects of the selection problem.

In Sumatra, results closely agreeing with those of Hamaker and Holle were obtained by Heusser,(9) who collected seed from the 1914 crop of four seven-year old mother trees and from this established trial plots.

When tapped for 13 months, beginning in 1920, the yields of the four mother trees were:

No. 1	..	21.6 grms. dry rubber per tapping.
No. 2	..	17.1 „ „ „ „ „
No. 3	..	18.8 „ „ „ „ „
No. 4	..	21.1 „ „ „ „ „

TABLE 3.

Tapping Period	Offspring of Mother Tree			
	No. 1	No. 2	No. 3	No. 4
Sept. 1918	2.7 grms.	2.6 grms.	1.7 grms.	1.5 grms.
Feb. 1919	4.1 „	4.9 „	3.1 „	2.7 „
Sept. „	7.4 „	6.1 „	5.8 „	4.6 „
Feb. 1920	10.2 „	12.8 „	9.2 „	7.6 „
Sept. „	11.5 „	14.3 „	10.2 „	8.3 „
Average	7.2 „	8.5 „	6.0 „	4.9 „

The numbers in the daughter plots were small, being respectively 34, 20, 23, and 23, making a total of 100 daughter trees. They were first tapped during September, 1918, and further records were taken for the months of February and September of the two following years. The average daily yield per tree in grammes of dry rubber is given in Table 3.

These figures show that the yield character of the mother trees is not transmitted consistently to the offspring and this inconsistency is further borne out by the variations shown by the single trees (Table 4).

TABLE 4.

Mother Tree	Total Yield: September, 1920	
	Worst Tree	Best Tree
1	206 grms.	2,433 grms.
2	416 „	2,900 „
3	550 „	3,030 „
4	286 „	2,077 „

In Table 5 the whole of the trees are roughly classified according to their total yields for September, 1920 and the same wide variation is seen.

TABLE 5.

Total Yield September, 1920.	Number of progeny.			
	No. 1	No. 2	No. 3	No. 4
0 — 1,000 grms.	14	5	14	16
1,000 — 2,000 „	15	11	7	5
2,000 — 3,000 „	5	4	1	2
3,000 grms. and over.	0	0	1	0

The best mother tree, No. 2, has most of its progeny in the middle yield classes while the worst, No. 3, has most in the lowest class which more than makes up for the presence of the one high-yielder. The numbers involved, however, are so small that further analysis is hardly justified.

From a review of all this work it is evident that a measure of improvement can be obtained by the employment of illegitimate seed from single high-yielding mother trees. The actual amount of improvement is, however, uncertain and not predictable. A tapping test of the progeny is essential before the value of a mother tree for this purpose can be ascertained and there is no evidence that this value will be the same for successive crops of seed. Lastly, mother trees should be classified according to tests of their progeny and not by their own yields.

(*b*) *The Production of Legitimate Seed.*

The pioneers in the work of producing seed by methods of controlled cross-pollination were Maas[10] in Java and Heusser in Sumatra.[11][12] Maas began by making a close study of the biology of the flowers of Hevea. These are of two kinds, male and female, but both are found on the same flower truss. The number of female flowers is relatively small, varying from three or four to over forty, but the number of male flowers is much greater. In spite of this Maas concluded that fruit setting was, normally, on a small scale and varied greatly in different trees. He estimated that under ordinary conditions, only 2-3% of flowers set fruit, an estimate borne out by Heusser who calculated that only one out of every 72 flowers set fruit.[10]

Maas further concluded that, although self-fertilization was possible, cross-fertilization was the rule in the natural state. When he enclosed inflorescences in wire cages covered with cheese cloth he obtained no fruits inside, whereas fruit setting took place if the flowers were artificially cross-pollinated. This agrees with the experience of Morris[13] who enclosed over 30 inflorescences in muslin bags and did not obtain a single fruit. In 1927 Mr. C. Alma Baker of Batu Gajah enclosed several inflorescences on two of his oldest trees in special bags made from sandfly-proof netting on the suggestion of the author. When inspected, the inflorescences were perfectly healthy but not a single fruit was obtained.

Nevertheless, self-fertilization cannot be excluded from consideration entirely. Maas himself described an isolated, native-planted tree which set fruit regularly but concluded that, in general, the capability for self-fertilization was so small that it might be left out of the question in comparison with cross-fertilization.

Finally, Maas drew attention to an important consideration affecting the establishment of isolated seed gardens. He emphasized that, before setting up such a garden by planting buddings from a good mother tree, it was necessary to be certain as to its fertility if disappointment were not to result. Further, if the seed garden were to be dependent on cross-pollination between buddings from more than one mother tree it would be essential for similar reasons to test beforehand the fertility of these with respect to one another.

Heusser of the Avros Experiment Station began work on the artificial pollination of selected mother trees in 1920.[12] He employed 20 parent trees in 35 different combinations which furnished altogether 6,716 pollinated flowers. The percentage which set fruit in one combination varied from zero—in four cases—to 39.3%. As a result the number of seeds harvested was 2,187, the number for the different combinations varying between zero and 244. The percentage of germination was 92.2%.

Self-pollination was attempted with six trees of which four proved sterile. One of the others furnished one fruit from 170 pollinated flowers, while from 131 flowers of the other tree nine fruits were obtained.

The results of this pioneer work, therefore, were mainly demonstrations of method, of the greatest value to the plant breeder, but as yet giving no clue to the possibilities of improvement to be gained from their employment.

After the above account was written there appeared an exhaustive review by Heusser of the character and production of his seedling crosses in their first three tapping years (December, 1925 to December, 1928). This is by far the most important contribution to the subject that has yet been made and it is unfortunate that this brief summary can give but a slight indication of the scope and importance of Heusser's work.(19)

With two exceptions the crosses were made in May, 1920 and planted out as stumps in October, 1922. Of the original 1,691 stumps 1,450 survived at the end of the third tapping year and of these 1,393 were tappable. Most of the casualties were due to root disease. The planting distance was 23 ft. by 23 ft. and trees were taken into tapping when a girth of 40 cm. was reached at a height of 1 metre. Tapping was begun in the fifth year on a half cut which was reduced to one-third in the third tapping year.

Heusser's first object was to compare the yield per acre of the whole number of crosses with that of an ordinary plantation. In the case of the crosses the number of trees per acre was less than normal, viz., 82 per acre, and in the first tapping year the yield per acre was only slightly better than the corresponding estimated yield for an ordinary plantation. In the second and third years, however, the yield of the crosses was respectively 166% and 140% of the estate yield, the yield in the latter year being 420 lb. per acre, i.e., when the trees were seven years old. It should be remembered, however, that the change over to the new one-third cut was made for this year.

No less than 30 families were represented and the yields of the various families differed considerably. Those in which M.T. 157 was one of the parents were amongst the highest producing whilst combinations with M.T. 145 produced the worst families. The first important result, therefore, that emerged was the expected one that certain mother trees gave rise to poor families while others invariably produced good families in spite of the fact that all the mother trees were originally good producers. Typical examples are furnished by the families 145 x 139 and 157 x 164. The first of these, consisting of 67 trees, gave an average yield per tree per tapping of 12.94 grms., whereas the second, which consisted of 34 trees, gave during the same period an average yield of 34.65 grms.

The next important question discussed by Heusser was the variation of yield within a single family. As he points out, the object of crossing high producing mother trees is to obtain valuable hybrids and, after a few generations, strains which are practically true breeding. From the latter point of view the families which show slight variation are the most valuable. The different ranges of variation are illustrated by the figures of Table 6 in which the trees are arranged in yield classes.

It will be noticed that in the total experimental trees the distribution of the yield classes is not very unlike that in a normal plantation population, most of the trees falling into the three lowest classes. In

TABLE 6.

Cross.	No. of trees.	Yield classes in grammes dry rubber.								
		10	20	30	40	50	60	70	80	90
145 x 138	132	39	53	26	11	3				
145 x 139	133	37	82	14						
138 x 139	70	2	39	23	8	3	0	1		
36 x 140	62	8	32	17	3	2				
157 x 164	66	2	2	15	28	14	4	1		
164 x 161	57	3	15	17	10	7	2	0	2	1
Total.	1393	207	589	361	154	62	12	4	2	1

the cross 157 x 164, however, the distribution of yield is much more regular, most of the trees falling in the third, fourth and fifth classes. Certain low-yielding families, e.g., 145 x 139, were quite as symmetrical but the mean yield was too low to make them of any value for selection purposes.

Considering single trees only, Heusser gives a list of no less than 70 trees, each of which had given an average daily yield of over 29 grms. (1 oz.) for the whole of the first three tapping years. The best tree, one of the family 165 x 161, gave during this period an average of 51.3 grms. (1.8 oz.) per tapping, while 22 trees gave yields of over 1¼ oz. per tapping.

These yields, reckoned as they are over three years, are surprisingly high in such young trees but the figures for the third tapping year are more remarkable still, no less than 11 of this group of trees giving more that 2 oz. of rubber per tapping.

Heusser also gives a valuable account of observations on the subsidiary characters of the experimental trees. He considers that thickness of bark is hereditary and that a thick bark is a favourable character. His remarks on Brown Bast are of particular interest. A census of the number of cases was taken over the whole experimental area at the end of the second and third tapping years and on each occasion the number of attacks amounted to 4%.

When considered by families, however, it was found that, with one exception, the highest producing families were the most severely attacked. For example, the crosses in which 36, 161, and 164 were parents were all seriously attacked while the mother trees had also shown signs of Brown Bast in 1921 and 1922. Heusser is therefore inclined to regard a condition predisposing to Brown Bast as hereditary.

All the crosses showed satisfactory bark characters and renewal.

Heusser is also inclined to regard the fertility of the crosses as hereditary. For example, M.T. 164 produces an abundance of fruit while M.T. 161 produces none. The seedlings from crosses with 164 are all prolific with the exception of 164 x 161. This is an important point for consideration when contemplating the planting of an isolated seed garden.

In the seed and leaf shapes of the crosses, sometimes the male parent appeared to have the upper hand and sometimes the female parent. This limits the practical value of these characters as a means of identifying the origin of the trees and, moreover, makes it imperative that the hand-picking of the seed should be relied on and not promiscuous ground-picking.

With his usual caution Heusser gives it as his opinion that his results have not simplified the selection problem. In this opinion he is far too modest for the results show very clearly to research workers the path to follow in future investigations and, at the same time, furnish definite warning evidence to those who so firmly believe that high quality selected seed can be produced merely by planting high-yielding trees in an isolated seed garden. Both research workers and producers are therefore under a considerable debt to him.

Heusser has shown that the crossing of two high-yielders does not necessarily guarantee a high-yielding family from the resulting seed. This result alone clarifies all our ideas on seed selection and the planting of isolated seed gardens, and it may now be regarded as established that only a tapping test of the progeny can decide whether the parent trees will produce a good family.

Again, Heusser's demonstration of the great differences in yield variability of trees belonging to the same family has shown clearly which is the type of family most suitable for selecting from. Furthermore, there is always the possibility of multiplying any outstanding tree of a cross by means of buddings to form a new clone.

A final conclusion of practical importance can be drawn from Heusser's work. A very clear indication is given that for many years to come reliance must be placed on budding rather than on seed selection for purposes of yield improvement.

IV.—The Scope of the Problem.

At this point it might be well to formulate the ideas underlying the problem of the improvement of the yield of Hevea by methods of selection and breeding.

We have seen that, in most cases, the production of seed is due to cross-fertilization and that self-fertilization, although uncommon and probably difficult, is possible under some sets of conditions. In both cases true sexual reproduction is involved and some account of the sexual apparatus of Hevea is therefore necessary to an understanding of the principles involved.

(*a*) *Sexual Reproduction in Hevea.*

Excellent accounts of the biology and structure of the flowers of Hevea have been given by Sprecher,[14] Maas,[10] Heusser,[11] and Morris,[13] and the following summary is taken from the work of the last-named.

"During the flowering season the rubber tree produces masses of flowers, which are borne in bunches (inflorescences) towards the end of the leafy twigs where the new season's growth is starting. Each inflorescence is much branched and bears two kinds of flowers. The female flowers are situated at the ends of the central axis and of the main side branches, while the male flowers occur in much greater numbers on all the lesser shoots . . . . The flowers of both sexes are surrounded by a bell-shaped corolla of usually five yellowish petals. The female flowers can be distinguished not only by their terminal position but also by their greater size and by the small green button-like expansion at the base of the petals. When the bud opens, the round green ovary can be seen inside carrying on top three whitish lobes. These are known as the stigmas and form the receptive portion of the female sexual apparatus . . . . The male flower is yellow right down to its stalk, and on opening exposes a central white slender column surrounded by two rings of tiny yellowish rounded projections. These are the anthers, which soon split and set free the pollen as a slight yellow dust . . . . The pollen grains carry the male generative cells and if transferred to the stigmas under the proper conditions (pollination) they may germinate and fertilize the female. Subsequently the ovary will grow and become a fruit containing three or, rarely, more seeds. The whole of the woody fruit wall and the outside layers of the seed, including the hard outer coat with its characteristic colour and markings and shape, arise from purely female tissue, and though development does not take place without fertilization, no male substance enters into them. The embryo, which lies in the middle of the seed and later grows into the seedling, is, on the other hand, the direct product of fusion between the male and female germ cells, and inherits a mixture of the characters of both parents."

In other words, the seeds from any mother tree look exactly alike but, as a number of male parents may have taken part in their production, the seeds from different fruits may differ in genetic constitution. It is the embryo which produces the seedling: the rest of the seed ultimately vanishes, so that the amount of variation in the seedling progeny is decided in the first instance by the number of male parents involved in their production. Furthermore, this amount of variation will vary from year to year in successive generations, for it is unlikely that the same set of male parents in the same numerical relation will be involved every year.

Maas, Heusser, and Morris have, however, shown that the operation can be controlled within certain limits and male parents selected at will. This gives good grounds for expecting that at least some measure of improvement may be possible from the results of breeding but, unfortunately, throws no light on the problem of the purity of the seed from a high-yielding mother tree under natural conditions.

(b) The Natural Pollination Process.

Pollination should be carefully distinguished from fertilization. The former is merely the process which results in pollen from a male parent being brought mechanically to the stigmas of the female. On arrival safely there, several factors may yet prevent fertilization. The surface of the stigma may be non-receptive, the pollen may be unable to germinate and so on.

Strangely enough, the actual process of pollination has not yet been observed. According to Morris[13], the structure of the flower, the stickiness of the pollen and stigmas and the presence of scent and colour indicate that insect pollination is more probable than wind pollination. He states:

"Many kinds of insects may be seen flying round the inflorescences and several workers in the Dutch East Indies have observed the flowers being visited by bees, flies, moths and beetles of several families, but they do not state that these insects were actually seen to enter female flowers. During the flowering season of 1928 the same families of insects have been seen on Hevea inflorescences in Malaya. Three or four sorts of bees have been frequently watched while visiting the male flowers for pollen and have been captured and examined. The baskets on their legs have been observed to be filled with pollen, which, under the microscope, has been identified as that of Hevea. Nevertheless, so far, not one has been seen to enter a female flower, the nearest cases being two which paused on the edge and then turned away.

"Smaller numbers of bugs, caterpillars, weevils, ladybirds and other beetles, flies and ants have also been observed . . . Occasional flies have been seen entering male flowers, but the only insects seen with certainty in a female flower have been two minute beetles and one tiny fly . . . It appears probable, nevertheless, that the more numerous and active bees are responsible for pollination."

It is possible that the capture of a number of bees visiting a particular tree, and the microscopical examination of the pollen carried by them, might afford a clue to the number of male trees previously visited.

(c) *Possible Methods of Improvement.*

The methods of improvement based on the fertilization process may be classed under the heads of Selection and Breeding. Selection may consist of taking a number of plants of one type and maintaining this as pure as possible by eliminating from each generation any offspring which appear to depart from it. The plants are allowed to cross-fertilize amongst one another until a generation is obtained which as far as possible is true to type. This is practically the method of inbreeding adopted with pedigree stock and its success depends upon the drastic elimination of all non-typical plants. It is a long and laborious process, for each stage entails a satisfactory yield test and the planting out of each generation in a different isolated position from the last one. It does, however, provide a perfectly feasible method for the improvement of Hevea up to a certain point upon which qualification Morris has the following remarks to make:[13] "It must be remembered, however, that no new hereditary factors can be brought in by this method, and if the full expression of a certain character is determined by the combination of several inherited factors (and many such characters are known in genetics), but all are not present in the original parents, then no amount of continued inbreeding will produce a race with that particular character developed to the fullest possible extent."

The limitations of this method, which is a combination of mass selection with inbreeding, should be borne in mind before adoption.

The above considerations enable one to have a clearer idea of the value of what is ordinarily known to the industry as "selected seed." This is seed collected carefully as regards condition but indiscriminately as regards parentage from high-yielding estate areas. As ripening does not take place in all trees at the same time the composition of a collected sample will vary throughout the seedling season. Further, the highest yielders generally fruit the least freely while a certain proportion of low yielders usually survives the thinning out process. The chances are therefore against the seed being as good as that now represented by the stand of high-yielding trees of the area. It would be better if the term "selected" were not employed for anything inferior to single tree collections.

The most promising line of progress is a continuation of selection work like that described by Taylor[6] by testing single tree selections from the progeny, provided these are self-fertile. Should this not be the case the most promising lines will have to be crossed with one another in an attempt to secure a better combination of characters.

Seeing that the possibilities in one direction are very restricted it will be of interest now to examine the extent to which methods of artificial self- and cross-pollination appear to promise assistance.

If a mother tree proves to be self-fertile, a series of selfings will ultimately enable a worker to produce a line of plants which are to all intents and purposes pure with respect to the desired characters, provided these are in the mother tree to begin with, although the operation will prove a lengthy one. The actual course of the work will proceed as follows. From a yield test of the progeny obtained by selfing the mother tree a selection will be made which will consist of a few trees nearest the average yield for the whole and a few of the highest yielders. The selected trees will then be selfed when old enough and their progeny again planted out. This procedure of selection, selfing, planting, testing and again selecting will need to be continued until a uniform line is obtained. If the trees are consistently self-fertile all this work can be carried out on an experiment station, that is, there is no necessity to isolate the plantings so long as the pollination is controlled and only the selfed seeds made use of. The disadvantages are of time and space. The latter sets severe limits to the number of possible selections while the former is consumed by the intervals of waiting for the results of yield tests. It is for this reason that it is so urgent to search for any connection between productive capacity and botanical characters in order that these waiting periods may be decreased if not eliminated.

The last method is that of artificial cross-fertilization or hybridization. Two superior parent trees are chosen and crosses made between them. This first hybrid generation is known to geneticists as the F_1 generation. The seeds will all resemble those of the mother tree externally but the resulting seedlings will differ widely in genetic constitution. Without going into further detail it may suffice to say that if the progeny are individually selfed and the seed batches sown separately to form what is known as the F_2, or second hybrid generation, some of the batches will remain true to type while the majority will show what is known as segregation or "splitting." That is, they will consist of mixtures of high and low yielders. All these latter will call for elimination as soon as a yield test has shown their true character while the others must undergo a further test. Tests of this kind must be carried out on their progeny until it has been shown beyond doubt that no segregation occurs. At this stage the particular line of plants concerned can be regarded as pure and as constituting a new variety from which seed can be produced for distribution.

This may take several generations to accomplish;

indeed, there is very little prospect of a definite result before the fifth generation although the fourth might possibly provide a variety reliable enough to serve as a temporary source of seed and lacking only the confirmatory test of purity to be carried out on the next generation.

The difficulties on the practical side are obvious. Theoretically, there are no more difficulties to overcome in Hevea than have already been successfully overcome with many cereals and pasture grasses. With such plants, however, it is possible to use small plots of ground and test very many lines on a small area. Again, it is possible to harvest one crop per year while the elimination of undesirable types presents no difficulty as the area must undergo cultivation after each harvest. In the case of Hevea a reliable yield test cannot be secured under five years from planting while the elimination of undesirables entails the cutting out of irregularly scattered blocks by no means negligible in size.

The additional complication introduced by the difficulty of self-fertilization is more serious and it can only be hoped that research will be prosecuted vigorously until this has been better defined. Experience in Java and Sumatra has shown that self-fertilization is difficult, uncertain and most probably uncommon; in Malaya it has not yet been found possible to secure it at all. Again, Heusser[12] has shown that, even if the mother tree be self-sterile, buddings taken from it may be capable of pollinating one another. Morris,[13] however, tested two clones for self-fertility but out of 409 flowers pollinated not one set fruit. With such large numbers the possibility of either the conditions or technique being at fault is excluded for cross-fertilizations were successfully obtained. One can only hope that, before long, more light will be thrown on this very disconcerting phenomenon.

V.—Recent Progress.

In general, work on the artificial fertilization of Hevea can be said to be only just begun and the volume of published work on the subject is small.

In 1919 Heusser made successful crosses between the mother trees of clones 35 and 36 (*see* Table VII). Twenty of the seedlings were tapped when about five years old and proved superior to buddings from the parent clone 35 and also from clone 49. Further details are yet not available but it is understood that the yield of the crosses has shown satisfactory increase and that by artificial pollination F_2 seedlings have been obtained which have been planted out in special seed gardens.

An important consideration must be taken into account at this point, namely, that of hybrid vigour. The hybrid which results from a cross often shows great luxuriance of vegetative growth, and if yield is in any way connected with the physiological vigour of the tree an increased yield would be expected on the part of the seedlings of the F_1 generation. In order to take advantage of this, vegetative propagation, i.e., by buddings or marcots, will need to be employed, for in the next or F_2 generation, raised from seed of the F_1 trees, splitting will occur. Heusser's later publications on this work will therefore be awaited with some interest.

The small amount of published work from Java is, naturally, mainly concerned with preliminary experiments, but work has been actively carried out during the past five years, not only by the research stations but by the Anglo-Dutch Plantations of Java. At the Besoeki Experiment Station of West Java, Schweizer[15] obtained 187 successes out of 936 crosses while Van der Hoop has reported successes varying between 5 and 35% for the four years 1923 to 1927 on the Pamanoekan and Tjiassemlanden properties of the Anglo-Dutch Plantations. One of Van der Hoop's crosses gave in its fourth year an average yield of 25 grms. of rubber per tapping which gives additional support to the opinion that the simple crossing of two high-yielding parents combined with budding from the F_1 generation may be expected to give some results in the direction of improvement. Van der Hoop has also a striking example of splitting in the F_2 generation which, so far as the writer is aware, is unique. This consists of a number of trees which are the selfed grandchildren —F_2—of mother tree 24. The difference in habit and leaf form is very remarkable. In another striking experiment which has produced seedlings from crosses carried out both ways between the same two parents, the trees bear a remarkable resemblance in habit to the maternal parent.

Van der Hoop began his work on the Pamanoekan and Tjiassemlanden in 1924 and has given a general sketch of this in *De Bergcultures.*(16) It is earnestly to be hoped that fuller accounts will before long be available.

The Central Proefstation voor Rubber began its work in 1927.(2) A feature of this is a well-planned attack on the subject of the factors which influence the percentage of success. Even at this stage the percentages obtained at the Proefstation appear higher than those obtained elsewhere and this work should be productive of results of great value to the breeder.

Crosses have also been made between some of the best Tjirandi clones but the following year similar attempts failed owing to mildew (*Oidium*) attacking the flowers. It is a matter for great regret that the workers in Java have to contend with such a serious disadvantage to research work.

More detailed accounts of experimental work have been given recently by Morris(13)(17) who began in May 1928 by making reciprocal crosses between two clones, A 44 and B 58. Where A 44 was the mother two fruits were obtained from 143 pollinated flowers but in the reverse direction 260 pollinations on B 58 furnished one fruit only. This led Morris to investigate the rate of growth of the fruits which set and the reason for the high mortality. In the survivors growth was noticeable about two or three weeks after pollination. From this point growth proceeded regularly until full size was reached in from 10 to 13 weeks. Casualties were greatest during the earliest stages but some fruits withered when between 6 and 9 weeks old.

The influence of the mother tree on the form of the fruit was evident. Both clones in the natural condition produce fruits characteristic in size and shape and the seed and fruit of the crosses resembled exactly those of the mother parent.

This is a point upon which further careful observation is required. Other species of plants which are normally self-fertilized often show great increase of fruit and seed size when artificially cross-pollinated and, in Java, the author was shown seeds from crosses of Hevea which did not resemble either parent which is surprisingly different from Malayan experience.

It has already been mentioned that no success was obtained with self-pollination. This was also the case in the second flowering season of the same year, viz., August to September. 195 flowers of four different clones were selfed without a single success being obtained. On the other hand crossings were made between seven different clones in 19 combinations and out of 1,248 crossed flowers on 186 separate inflorescences 91 fruits were obtained. These furnished 274 seeds of which 205 germinated.

These experiences are valuable as indicating that, even now, it is possible to apply a technique sufficiently good to yield an ample harvest of seed along any line of improvement pursued.

Some qualification of this is, however, necessary. Morris found that the success varied greatly with the different crosses, four combinations actually giving no successes while four others gave 20% or over. The results with reciprocal crosses were also variable. For example, crossing between A 44 and D 61 was almost equally successful in both directions, but with A 44 and B 16 the success was 20% in one direction and only 4% in the other.

Morris pointed out that the real success is represented not by the number of fruit obtained but by the number of seeds that germinate. Certain fruits yield light seeds which may be normal in size but undeveloped inside. These cannot be detected until the harvest and are a fruitful source of disappointment.

VI.—The Technique of Artificial Pollination.

The actual technique of self- or cross-pollination is simple and resembles that ordinarily employed in plant breeding work for other flowering plants with the exception that it is further simplified by the occurrence of the male and female portions of the sexual apparatus on separate flowers. Observation of inflorescences at different stages soon teaches one to recognize flowers of both sexes which are due to open on the following day. Armed with this knowledge the procedure when crossing two mother trees A and B is as follows:

One of the trees, e.g., A, is selected as the mother. An inflorescence is chosen and all the male flowers are removed with a pair of pointed scissors. After this all the females which are fully open are removed, then the very young buds until, finally, only those flowers are left which will open the next day. The inflorescence must now be protected against the visits of insects which is done by enclosing it in a cage of muslin stretched over a wire framework. One of the wires of the cage should be prolonged below so that it can be twisted round the shoot which bears the inflorescence in order to take the weight off the latter and the muslin should hang well down below the framework so that it can be twisted round and tied with string below the inflorescence. The size of the cage must be such as to enclose the inflorescence comfortably without damaging it and, if required, the weight may be further taken off the shoot by running a cord from the top of the cage to a nearby branch.

The inflorescence is left in this condition until the following day when pollination can be attempted. To carry this out an inflorescence should be chosen with a number of male flowers fully open but as a measure of precaution the inflorescence may be bagged on the previous day after cutting off all the male flowers which have already opened. The inflorescence is selected from Tree B and, when ready, is cut off and carried to Tree A. The bag is removed from the female inflorescence and pollination commenced. This consists of taking a small pair of pointed forceps and gently spreading open the petals of the female flower. With the forceps the central column of the male flower which bears the anthers is removed and the stigmas of the female flower lightly touched or dusted with it so that pollen is left adhering to the sticky receptive surface. After all the flowers are pollinated the bag is replaced and left for two or three days after which it can safely be removed.

If the operation has been unsuccessful the female flower will wither and shortly drop off. If fertilization has taken place then, according to Morris,[13] the ovary begins to grow, slowly at first but more rapidly during the second month, and reaches full size after two and a half to three months. Internal growth and development of the seeds continues until the fruit ripens about two months later.

So far, nothing has been said about the conditions suitable for the operation. Unfavourable weather conditions are always amongst the greatest difficulties of artificial pollination in temperate climates and it is obvious that such difficulties must be accentuated in a tropical climate. Further, successful crossings of many plants have only been achieved after a prolonged study of the development of the flowers, e.g., rice and many grasses, so that it is satisfactory to learn that the conditions affecting the success of the operation are being investigated both in Java and Malaya. From observations of the stage of opening of the flowers when pollinated and of the time of day when the operation was carried out Morris[18] has found that the success increased markedly from morning to afternoon. Flowers were pollinated at all stages but the operation was most successful in newly-opened flowers. Success was greatest on the afternoon of the day of opening and much less on the afternoon of the day before and on the morning after opening. In general, success was found to increase from morning to afternoon while the age of the flower and rain also appeared to have considerable influence.

It should be mentioned that the results from work of this kind need not necessarily correspond with those obtained in Ceylon or the Dutch East Indies where climatic conditions are different in addition to the time of flowering. Mass[10] carried out somewhat similar observations and obtained greatest success with flowers pollinated on the morning after opening and least with those pollinated at the midday after opening. Even now the rate of success is, in the opinion of the author, quite satisfactory and as great as is often obtained in crossing other plants.

A modification of technique has been introduced by workers in the Dutch East Indies to eliminate the troublesome work of bagging. Flowers just on the point of opening are used and the remainder cut off. Pollination is carried out by taking one or two anthers and, after opening slightly the corolla of the female flower, placing these within. A tiny plug of cotton wool is then placed in the throat of the female flower to hold the anthers on the top of the stigmas and the flower gently closed. So far as Malaya is concerned there is an objection to this method which would confine pollinations to the mornings when the rate of success is lowest.

VII.—The Present Position and Future Prospects.

It is now possible to take stock of the position and so far as seed selection is concerned to make fairly definite statements. By taking seed from a high-yielding mother tree it is possible in most cases to obtain a higher yielding stand than by employing an ordinary sample of seed. The actual amount of improvement, however, cannot be foretold; a yield test of the progeny is still required in order to determine this.

It cannot be assumed that the sample of seed will give uniform results for different years of collection unless the mother tree is isolated and also self-fertile.

Further progress from this stage will necessitate rigid selection of the progeny, combined with selfing or crossing, on a properly-organized experimental area. This selection will need to be continued until a reasonably pure line is obtained. At this stage it is unlikely that the mother tree will have been greatly improved upon except in the direction of uniformity—ultimately purity—of seed potentiality.

If self-sterility proves an obstacle, the employment of buddings may enable this to be overcome. The fertility of buddings from self-sterile mother trees needs immediate investigation in Ceylon and Malaya for results in the latter place do not, so far, support the results obtained by Heusser.

So far as research on breeding is concerned a satisfactory technique has been developed, capable, where required, of being applied on the plantation. More light is needed on the subject of the conditions which make for success but investigations now being carried out in Java and Malaya should soon provide this.

Isolation gardens need careful consideration before being set up. It is essential to be certain as to the fertility of the trees before planting them. If the garden is to contain a single clone this must be proved to be self-fertile beforehand or no seed will be developed. If it is intended to plant more than one clone it must be determined beforehand whether the clones will come into flower together and whether they will cross successfully. With two self-sterile clones which will cross with one another two kinds of seed are possible according to which clone is the maternal parent. The probability is that these two kinds will be present in very different proportions. Should both clones be self-fertile and also cross, two kinds of seed will be present in each clone. The complicated nature of the harvest from a seed garden containing a number of clones can be deduced from these simplest of illustrations.

At every stage a selection can only be valued according to the yield of its progeny so that an organized tapping test on the latter is essential if propagation by seed is wished for. The productive capacity of a selection can, however, be transferred directly to the field by means of buddings.

In the first hybrid generation abnormal vegetative vigour is to be expected. The next generation from seed would show segregation or "splitting" but, again, the vigour of the hybrid can be transferred to the field by budding. Should hybrid vigour alone be reflected in yielding capacity this method may prove useful in practice.

A method for diagnosing high-yielding capacity in young plants would materially shorten breeding and selection programmes.

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CHAPTER III

THE EARLY DIAGNOSIS OF HIGH YIELDING PLANTS

I.—Preliminary Considerations

It has already been mentioned that a serious disadvantage in all selection work on Hevea is the long period which must elapse before a satisfactory test can be obtained of the productive capacity of a new generation. Moreover, the same amount of time and space must be devoted to the inferior progeny as to the superior, for the former cannot be eliminated until the results of the test are obtained. The latter cannot usually be commenced until the fourth year and must be continued for at least two years which means that, in an experiment involving four generations, a minimum of 25 years must be allowed for.

The ability to make an early diagnosis of high productive capacity would not necessarily shorten this period to any appreciable extent but, as it would allow attention to be devoted exclusively to the superior progeny and the inferior to be eliminated, the reduction of space and labour would be very considerable.

But it is another sphere of activity that a method of early diagnosis has been eagerly demanded, namely, in the normal planting up of a new clearing with stumps from a nursery or, alternatively, in the close planting of seedlings combined with subsequent drastic thinning out of all but the élite.

In making this demand a good deal of misapprehension of the possibilities has always been evinced. A selection operation always involves the choice of a small number of superior plants from a large population of which the great majority are inferior. The selected plants themselves are not improved during the process nor, unless they are large enough in number to form a new population, can any mass improvement be expected in this first selection stage. In other words, one cannot get out of the nursery more than there is in it.

It is well known that the trees of an ordinary estate population, raised from the same batch of seed and grown under uniform conditions, show great variations in productive capacity. This variation has been studied by several investigators and their conclusions have been substantially in agreement. It has always been found that the great majority are below the average in yield, and that the proportion of superior trees is small. This has led to the development of the opinion that if it were possible to increase the number of the latter at the start, by selecting only these classes from a large initial population, it might be possible to plant up an area which was high-yielding by pre-determination.

This is perfectly sound in theory and very attractive but, in practice, the disadvantages are weighty enough to be worth consideration. Both these and the possibilities can most easily be seen in an examination of one of the researches referred to above. The most favourable case is provided by the investigation carried out by Taylor in Ceylon on the progeny of the tree Heneratgoda No. 2.[1]

Taylor's results have already been discussed in Chapter II so that it will be sufficient in this place merely to recall that the investigation was carried out on 161 trees which remained after thinning an original planting of 252 trees. The seedlings were all progeny of a single tree and were planted originally 20 ft. by 15 ft. When tapped alternate daily in their eleventh year, 44 of the trees yielded 7½ lb. or over and of these ten gave 10 lb. or more.

Had all the trees been of the first category, then, with a stand of 80 to the acre, the yield per acre would have been 600 lb.: had all the trees been of the 10 lb. class it would have been 800 lb. But the 161 trees tested were part of an original planting of 252. Allowing for 10% of rejections at planting owing to poor development, forked roots, curvatures or disease and assuming a satisfactory germination percentage of 60, in order to obtain the 44 plants of the 7½ lb. class, it would have been necessary to sow nearly 500 seeds.

From this it is easy to calculate the number of seeds required to produce the 80 stumps for one acre of clearing in order that this shall have a yield of 600 lb. in its eleventh year. The actual numbers involved are 854 seeds and 470 stumps.

This case is a much more favourable one than would be encountered in actual estate work for reasons already specified. Even so, the result compares very unfavourably with the one which might have been produced by planting an equivalent number of buddings from one of the best proved clones. Moreover, no method of early diagnosis would have assisted in prognosticating a definite result; the utmost it could have produced would have been the best possible result from the original population.

Again, for application in the field, due regard must be made to the practicability of the method but, in this connection, a method impracticable for estate purposes might still be used with advantage in research work. Under this heading would fall those methods which involve the chemical analysis of a portion of the plant or the use of the highest powers of the microscope, but a discussion on practicability will be reserved until a survey has been made of the results of research work already carried out.

II.—Application of Chemical Methods to the Problem.

In 1922 Bobilioff published an account of his investigation into the relationship between the yield of the tree, the quantity of latex in unit volume of the bark and the actual number of latex vessels present.(2) It was not actually the first investigation of this kind, for he refers to an earlier publication by a Dutch worker, Tromp den Haas, of the results of work on somewhat similar lines carried out 14 years earlier. Tromp den Haas only worked with three trees and came to the conclusion that no clue to the quality of the tree could be obtained from the investigation of the rubber content of the bark. Bobilioff, however, showed that a definite relation did exist between the productive capacity and the quantity of rubber in unit volume of the bark. It was slightly closer than that usually found between yield and number of latex vessel rows, but not so close as that between yields and number of latex vessels. As the latter quantity is easy to determine the conclusion appears to be that the more troublesome determinations of rubber content are unnecessary.

The analytical methods involved are not only far from simple but are subject to several experimental errors. This probably accounts for the absence of records of further work until 1928 when a paper appeared by de Jong, the former director of the A.V.R.O.S. experimental station, on the application of chemical analysis to the selection of Hevea.(3) Reference should be made to the original for details of the methods employed; essentially, these consisted of estimating the rubber content in the leaf-stalks of trees which included buddings from clones 49, 50, and 152 and also a normal low-yielding tree.

De Jong chose the leaf-stalk as the object of his investigation because he considered that it might be expected to contain a definite quantity of latex characteristic of the tree. It is a matter of common knowledge that if a leaf-stalk is severed quite close to its base no flow of latex occurs, although if the cut is made a short distance from the base a flow is obtained. Bobilioff explained this by showing that at the base the connection of the latex vessels of the leaf-stalk with those of the shoot is broken.(18)

This expectation was not realized for de Jong found at once that the rubber content varied with the length of the leaf stalks, being greater in the shorter ones, which disposed of the possibility of the rubber content of the leaf-stalk being constant and characteristic for a particular tree.

Naturally, no direct relation was found between the rubber content and yield; in fact the opposite was found to be the case when clone 50 and the low-yielding tree B were compared. Nor was there apparently any relation between the yields of the three clones and their rubber contents. This does not mean, however, that the last word has been said on this subject. It is still possible that, with improved analytical methods and a better choice of material, the relation between productive capacity and rubber content may be much more closely defined. The continuation of work advocated by de Jong is therefore eminently to be desired.

The variation of rubber content with length of leaf-stalk, discovered by de Jong, is of the greatest importance as showing the absolute necessity for a combination of botanical and bio-chemical work on the selection problem. From another source(4) it has recently been reported that a microscopical investigation of a whorl of leaves shows the existence of a decreasing size gradient in the correspondingly situated cells of the same tissue from the lowest leaf-stalk to the highest. In consequence, it is not to be expected on botanical grounds that the proportion which the latex-bearing tissue bears to the whole leaf-stalk should be constant for different stalks. The same applies naturally to their contents. This very interesting point will be returned to later.

III.—LATEX INVESTIGATIONS.

There is a considerable body of literature on the microscopical investigation of latex and an admirable summary of this has been given by Hauser.(5) Under the high powers of the microscope a drop of latex is seen to consist of countless particles in vigorous movement in a colourless fluid. These particles constitute the caoutchouc portion of the latex and the process of coagulation comes about from their coalescence and, finally, clotting. A small proportion are spherical but the majority are either oval, pear-shaped or oval with a pronounced tail. Some particles are so small as to be outside the range of vision of an ordinary microscope and the visible ones show great variations of size as well as shape. Expressed in thousandths of a millimetre (microns) the diameter varies from ½ to 3 and the length from ½ to 6.

The average dimensions encountered in the same tree vary according to the conditions. When a tree is brought into tapping after a rest period the latex contains chiefly larger particles. During the next few days the average size decreases, reaching a minimum after about eight days of tapping. It then rises to reach a constant value after a further eight days. These variations correspond with the variations of rubber content during the first days of tapping.

It is the shape rather than the size of the particles which has attracted most attention. Bobilioff was the first to investigate them from this standpoint[6] and show that in the younger portions of the tree the particles were chiefly spherical while the pear-shaped particles predominated in the older portions and in the roots. But, in spite of these variations, Heusser found that in an individual tree the latex contained particles of a shape characteristic for this tree so that with practice he was able to determine the tree from the sample of latex under the microscope. Further, he found this characteristic shape to hold for all the trees of a clone. Hauser's brilliant researches form the first attempt to use the latex actually for diagnostic purposes and, although the methods are such as to be restricted to the research laboratory, it is to be hoped that they will serve as the starting point for more intensive work.

Quite recently a further striking contribution to the microscopy and bio-chemistry of latex has been made by Frey of the A.V.R.O.S. research station.[7] Frey discovered that the particles visible under the microscope were not all caoutchouc particles as had been assumed by previous workers. Some of the spherical globules were found to be resin particles and to be the bearers of the yellow pigment characteristic of certain latex samples. In trees which actually produced yellow latex the pigment was found to be absorbed in the spherical resin particles but not always to the same extent. The resinous nature of the particles was confirmed by bio-chemical tests carried out on the stage of the microscope and the investigation continued on three other species of Hevea, namely, H. Collina, H. Spruceana and H. guyanensis. Specific differences were determined for these. In the first named the particles were relatively enormous; in the second they were smaller than in H. brasiliensis while in H. guyanensis they were larger.

Taking all these researches into consideration the conclusion is clear that, from a systematic point of view, the study of latex has only just been begun and that the further prosecution of bio-chemical research must add greatly to our knowledge of the specific differences between different types of Hevea.

With reference to Frey's discovery, although it is outside the scope of the present work, attention may nevertheless be directed to its importance from the manufacturing point of view.

IV.—Investigations on Latex Vessels.

Attempts to demonstrate a relation between yield and some character of the latex vessel system have been very numerous. Investigations have usually been carried out on adult trees and conclusions as to any diagnostic value of the results have been implied rather than direct. The difficulty of investigating the young latex vessel system of the seedling probably accounts for the paucity of our knowledge of it, and the position is made more difficult by the fact that other factors than the actual measurable characters of the latex vessels affect the flow of latex from the plant. The idea has often been mooted of applying some form of tapping test to the seedling and assuming a relation between the flow of latex from it and the efficiency of its latex vessel system. The kind of test advocated has usually been a pricking or cutting of the bark combined with an estimate of the number of drops which exude. The drawback to a proceeding of this kind is that the physiological activity of the seedling varies throughout a given month and that the seedlings of any nursery are in different states of activity on any given day. Consequently, a different result would be obtained if the test were repeated after an interval. From the practical point of view there is a much more serious objection which will be treated of later.

In the adult tree the character of the latex vessel system which has been investigated most fully is that of the number of rows in the cortex. This, of course, has no value as a diagnostic character nor has the actual number of vessels which was investigated by Bobilioff. A character which might be expected to have some diagnostic value is the actual size or cross section of the vessels provided that this is uniform from the seedling onwards.

The first investigator to consider the value of the diameter of the latex vessels was Bally[(8)] who wished to ascertain the reason why certain trees which possessed only a few latex vessel rows were yet high-yielders. Bally states (page 336) that he was straight away inclined to ascribe an important role to the diameter of the latex vessels, and on that account carried out measurements of the latex vessels in different trees. He found, however, that the difference of diameter in one and the same latex vessel was very considerable and that the latex vessels of one and the same sample might be very different in size. He illustrated this variation by a drawing of one of his preparations showing the places where ten of a series of measurements were made.

Bally then gave the results for five trees in more detail, his results for diameter measurement being summarised in Table I. The measurements are given in thousandths of a millimetre.

TABLE I.

Tree	Latex Vessel Diameter			Order of Yield		
	Maximum	Minimum	Average	1920	1921-22	1922-23
1.16	20	10	15.7	2	2	5
1.47	23.3	13.3	17.9	4	4	2
1.86	26.6	13.3	18.1	3	1	8
1.149	26.6	10	20.7	1	3	3
1.159	28.3	13.3	19.2	5	5	1

He then took the average yield per tapping for each of the previous three years and found that there was no relation in the case of any year between yield and latex vessel diameter.

From 1924 onwards there is an absence in the literature of any further reference to work on latex vessel diameter until last year and Bally's conclusion that "the diameter of the latex vessels is not an important factor, there being no correlation between the diameter . . . . and the production" represented the current view of the position.

Between July and December, 1928, however, there appeared in various planting journals and in the daily press accounts of what later became popularly known as the "Ashplant Method" or "tube bore theory."(9) (10) Contrary to Bally's experience Ashplant claimed to have established a mathematical correlation between latex vessel diameter (tube bore) and yield which was so high that it proved "latex tube bore to be the chief factor determining yield."(11)

The "discovery" was received in research laboratories with either coolness, reserve or searching criticism which formed a marked contrast to the enthusiasm with which it was received by the planting community. In general, the critics withheld comment on the actual method on the ground that Ashplant had not given adequate details of this, and restricted themselves mainly to showing the impracticability of the method in practice even were its accuracy confirmed.

In consequence, interest in the method has almost lapsed but, in view of the great importance of early diagnosis of yielding capacity, it will be of advantage to summarise what can be gathered of the method from a survey of the various articles and, afterwards, to discuss the various criticisms that have been advanced against it.

Ashplant stated that, as a result of a study of the incomplete relation between the yield of a tree and the number of latex vessel rows in the bark, he came to the conclusion that there must be some other anatomical factor which upset this relation in a number of trees and that this factor was the "bore" or diameter of the vessels. He was unable to secure satisfactory measurements of diameter from the vessels in bark samples owing, as he stated, to distortions produced by secondary growth. He sought, therefore, a region in the tree where no secondary growth took place and where the latex vessels occurred in their original form.

This region proved to be the leaf-stalk, but for some reason Ashplant did not communicate this fact(9)(10) until six months later,(11) which led readers to conclude that his work had really been carried out on bark samples and that the proof had been made possible by improvements in technique, enabling him to overcome the difficulties attending the determination of average latex tube bore.(10)

"Tube bore" measurements were carried out on 239 trees, 120 measurements being taken in each case and the average calculated. The same trees were test tapped and the average volume of latex per tapping calculated. The tapping system was not described nor the number of days specified.

From the latex yield figures and the "bore" measurements a correlation table was constructed from which the coefficient of correlation was calculated to be 0.76. From this Ashplant formed the conclusion that "the tube bore formed 76% of the determining influence in yield."

This is, of course, a misunderstanding of the meaning of the correlation coefficient. A coefficient of 0.76 shows that only 35% of the variation in yield is due to the variation in "tube bore"; there is still 65% of variation to be accounted for, about one-third of which is due to the number of rings and the rest to physiological factors which up to the present have not been sufficiently investigated.

For practical purposes Ashplant claimed that the importance of his discovery lay in the fact that he had proved that trees with a "tube bore" of less than 14 microns under no circumstances gave high yields while those with a "tube bore" of 15 to 20 microns were good yielders under all circumstances. (A micron is one-thousandth of a millimetre). Another class, presumably those trees with a "tube bore" between 14 and 15 microns, might be good yielders if the number of rings in the bark was sufficient. In consequence Ashplant claimed that, at the age of six months, trees could definitely be classed as bad, medium, good, and very good.

Later,[11] Ashplant modified these claims very considerably and stated that the trees with the largest "bore" were not necessarily the highest yielders, for the important factor of ring number had to be taken into account. On the question of practicability he stated that he was able to "make a rough estimation, good enough for practical purposes, in a few seconds."

A considerable body of criticism began to develop as soon as publicity had been given to the method. In a review of this in *De Bergcultures*(12) by a member of the staff of the Java Proefstation voor Rubber the reviewer stated that the original article gave occasion for great expectation but that, from the scanty data furnished, it was impossible to form a just opinion of the correctness of the theory or of its applicability in practice. On the latter subject he dealt at length with an analysis made by an experienced Malayan planter, C. C. Mallet, (*Straits Times*, Singapore, July 19th, 1928), who demonstrated that on grounds of expense and personnel it would be impossible to apply the method economically in planting up 500 acres.

The reviewer went on to state that, although sufficient data were not available from which to judge with certainty, the great danger was that the method would prove to be unserviceable in the plantation on account of its complicated nature. He emphasized that the counting of latex vessel rings as an aid to selective thinning out had failed to gain a footing in plantation practice for this very reason and added that it was only to be expected that the measurement of latex tube diameter would be a much more difficult technical operation than the fairly simple ring counting method.

In conclusion the reviewer made fresh reference to the opinion of Bobilioff, the well-known investigator of the Proefstation, that, owing to technical difficulties, exact measurements are impossible.

Shortly afterwards,(13) Bally drew attention to the fact that Ashplant had not evidently been aware of his previous work although this had been published in the *Archief voor de Rubbercultuur*.(8) After resuming the work in question Bally stated that it was impossible to account for the contrary results obtained by Ashplant until the appearance of his promised documented report to which all rubber botanists were eagerly looking forward. In the meantime he conjectured that Ashplant's conclusions had probably been based on more abundant measurements than he himself had carried out and that it might in this way be possible to obtain reliable measurements from a tree. Nevertheless, even if this should prove really to be the case, Bally considered that it would still be wrong to rely on this character alone for judging the productivity of a Hevea tree as many years' experience in the Dutch East Indies had shown that the number of latex vessel rows also played a part.

A more weighty and critical review, however, was published later by de Vries,[14] portions of which are of so much interest that they will be quoted almost in full. De Vries began by stating that it was a good scientific practice to support every conclusion with the facts that were available. When the facts are given without restriction anyone can decide for himself whether he is in agreement with the conclusions drawn from them. Ashplant, said de Vries, had sorely tried the patience of his readers in this respect. His first publications nowhere gave any indication of the method employed nor how his figures were obtained. His lecture in December, 1928[11] gave some results and revealed that the latex vessels of the leaf-stalk and not those of the bast had been measured but said nothing about the preparation, staining and measuring of the vessels. Others, therefore, were not in a position to follow closely the researches of Ashplant according to the methods employed by him and, even if they essayed this and obtained definite results, they would still be uncertain of not having missed some special feature of the method. Moreover, de Vries considered that the publications of Ashplant did not reveal in a convincing manner that the measurements had been obtained in the sense described by him.

It was not to be wondered at therefore that such unusual methods in scientific circles had caused a certain amount of reserve especially as it was known that a number of workers had previously made researches in the same direction without reaching the same results.

On the method itself de Vries has the following cogent remarks to make. Ashplant finds a high correlation between latex vessel diameter and yield in nine-year old trees. In seedlings he finds the same figures for diameter occurring in the same frequency. The conclusion that the diameter measured on the young plant will be correlated with the yield when the plants are older is not proved nor can it be proved until the young plants which have been measured have reached a tappable age. Moreover, the diameter measurements given are the average of 120 measurements. In practice such a large number would be impracticable and one would have to be content with a few. With smaller numbers the experimental error might be considerable and result in a much lower correlation, but nothing is said on this important subject.

De Vries then went on to consider what would be involved in the planting up of a hectare (2.4 acres) by the Ashplant method and after discussing the number of plants to be investigated and the personnel required concluded that it would be a gigantic operation. According to his calculations, even if only the 26% of worst seedlings were eliminated by means of diameter measurements, for the planting up of 240 acres, three teams, each consisting of four laboratory workers, would be required and it would take these four months to get through the work. On the other hand, if it were required to select out the 25% best seedlings for planting, four times this length of time would be required.

In conclusion de Vries considered that in real selection work the method might be worth attention. It would never be possible to draw direct conclusions from the results or dispense with tapping tests but, in the case of a large number of mother trees in a collection for experimental purposes, it might serve as a means for a preliminary sorting out of mother trees until tapping figures were available.

In a later communication, de Vries, Schweizer and Ostendorf have pointed out that one of the difficulties in selection work on Hevea is that there is no correlation between the production of a mature tree and any character which can be recognized in the young plant. Nor is there any relation between the yield of the young plant and that of the adult. They stated that Ashplant claimed that the diameter of the latex vessels of young plants gave a direct indication but that, as earlier attempts in this direction had been unsuccessful, it was necessary to await details of the method in question before a conclusion was possible.[17]

The method has, naturally, attracted attention also in Ceylon and, in a review of Ashplant's lecture,[11] criticism along much the same lines is expressed in the *Tropical Agriculturist.*[17] The reviewer states: "It is a pity that Mr. Ashplant has not published a detailed account of his experiments and it is to be hoped that he will do this as soon as possible. He has not told us the variation in latex tube diameters in one petiole nor the variation in latex tube diameters of a number of petioles from one tree . . . . until full data are published and contributory experiments have been carried out elsewhere, confirmation of the theory must be withheld, particularly in view of the criticism put forward by Malayan workers."

None of the above statements deal with work carried out by the writers themselves, with the exception of that of Bally, but further criticism has come from Ceylon as a result of a definite attempt to confirm the truth of the theory. At a meeting of the Estates Products Committee of the Board of Agriculture held on May 7th, 1929, Mitchell, the Secretary of the Rubber Research Scheme, gave an account of work started about six months previously by Taylor.[15]

After emphasizing that, in the absence of a detailed account of the method employed by Ashplant, they were neither in a position to say how his investigations were carried out, nor to criticize the method, Mitchell went on to state that, so far as could be seen, the method entailed the use of an expensive projection apparatus. On this point he concluded: "It seems curious that Mr. Ashplant should declare that it is a very simple method and, presumably, could be worked by anyone. But it appears to us, so far as we are able to judge, that it will only be possible in some laboratory, and by a scientific observer."

Referring to the actual work carried out, he went on to state: "Any way, the results Mr. Taylor has got . . . . are to the effect that there is a definite relationship between latex tube bore and yields, just as there is a relationship between latex yield, girth, bark thickness, etc., but he has not been able to find quite as high a relationship as Mr. Ashplant has found. In fact, some of his trees which are very high-yielders had not that large bore which Mr. Ashplant says is a prime factor . . . . So the position at the present moment seems to be one of a certain degree of doubt. We cannot criticize the theory in the absence of facts."

The position is therefore that there is a formidable body of criticism of the method but, as yet, nothing in the way of confirmation or support from any independent source. Moreover, the work of Taylor referred to above, so far from supporting the theory, gave additional reasons for caution. Up to the present no other research worker has published conclusions based on actual work although it is known that several have tried out the method with unsatisfactory results. For example, the writer compared the yield with the diameter of the latex vessels of the bark of seven different clones, varying greatly in productive capacity, without being able to find any clear relation between the two. Further, it was found that at least 200 measurements were necessary in order to obtain a reliable mean value for diameter. Other discordancies were encountered. For example, the lowest mean value for any clone was 22.7 microns so that, judged according to latex vessel diameter, all the clones would have been placed in Ashplant's high-yielding class. But, when tapped alternate daily in their fifth year, three of them yielded less than 6 grms. of dry rubber per tapping, the lowest yield being 2.2 grms. as compared with 18.5 grms. for the best clone.

Had a selection of the four best clones been attempted, using latex vessel diameter as a criterion, the selection would have omitted the best and third best but included the fourth and fifth. Further, had the elimination of the four worst been decided on the same basis, only the second, fourth, and fifth best would have been retained. When it is added that only the three best were worthy of retention (18.5 grms., 14.3 grms. and 13.3 grms.) it will be realized that, even as an aid in clone selection, the method cannot be regarded as reliable.

The above examples are quoted since they bear on the suggestion of de Vries[14] that it might be of interest to examine the diverse collection of mother trees assembled at the Proefstation from many quarters. He thought that, before tapping figures were available, it might be possible to regard less hopefully those with small latex vessels and take more interest in those with wide ones. The examples just quoted show, however, that any actual selection made before tapping figures were obtained would be very unreliable.

Most of the critics have stated their inability to criticize or follow the method itself before the full account promised by the author is published. Consequently, several interesting points have not yet been discussed. For example, nothing has been said about the validity of the tapping test nor have any particulars of this been vouchsafed. The yields were apparently determined in terms of latex volume, a method which all research workers regard as unsatisfactory. In this particular case nothing is said about the dry rubber content or the scrap. If, however, an average dry rubber content is assumed for all the trees, it will be seen that no less than 75 of Ashplant's trees gave at the age of nine years an average yield of less than 6 grms. of dry rubber per tapping. With such small yields the scrap would form a considerable portion of the daily production so that had the yield been determined in grms. of dry rubber the correlation might have been very different from the one obtained.

Furthermore, only 15 trees out of 239 gave an annual yield of more than 7 lb. and of these only three were 10 lb. trees. (This is on the assumption that tapping was alternate daily on a half-cut). No less than 186 trees yielded less than 5 lb. and of these half yielded less than 3 lb.

Again, the variation in girth was very considerable—from about 18 to 39 ins.—so that the cut must have varied from 9 to 19 ins., while the actual number of latex vessels cut by the tapping knife must have varied more widely still.

The question arises, therefore, as to whether the trees really formed a normal Hevea population for should this prove not to be the case the correlation is, of course, meaningless.

It should be emphasized, however, that most of the critics have confused the theory with the method. The correlation which was obtained by Ashplant as the result of measurements which occupied about three months was only used to establish what was, in his opinion, a direct relation between diameter and yield. The method he advocates does not depend on actual measurement: indeed he has stated, "The actual measurement of latex tubes is, of course, impossible commercially, and ways of more rapid assessment had to be explored." The actual method appears to involve the preparation of sections and the magnification of these on a screen by means of a projection apparatus of the epidiascope type. The trees are then classified by eye estimation of the diameter of the vessels. (*See* Proceedings of the 35th general meeting of the United Planters' Association of Southern India, 1928). But in making an estimation of this kind on the trees he had actually investigated, Ashplant was wrong in 13 cases. On going back to the sections of these trees he found that all, i.e., 5.5% of the whole, were defective, but that new sections gave him the desired result.

The assumption that sections of one leaf-stalk will give reliable measurements of "tube bore" also needs confirmation. Attention has already been drawn to the fact that, for cells of the same tissue, there is a regularly decreasing size gradient from the base of the leaf-stalk to the tip, and in correspondingly situated cells of the same tissue from the lowest leaf-stalk of a whorl to the uppermost.[4] That is to say, if sections of a stalk are taken 1 in.

from the base and tip respectively, then in any tissue, pith, cortex, stone cells, epidermis and wood, the cells of the first section will be greater than those of the second. Or, if two leaf-stalks are taken and sectioned at equal distances from the base, then the cells, for example, of the pith will be greater in the section of the lower leaf-stalk. It is interesting to note that Ashplant's own sections bear this out, although he does not appear to have noticed it. The section labelled A 46 is taken from near the base while A 31 is cut much nearer to the tip, the radii of the two being roughly in the proportion of 15:12.

The author has measured this gradient in sections of the same petiole taken 1 in. from the base and tip respectively. The method employed was to photograph the sections on standard paper, cut out the tissue concerned and compare the weight of this with the weight of a standard area of the same paper. The area of the tissue divided by the number of cells gave the average area of the latter, and the magnification being known it was possible to calculate the true average. The results are summarised in Table II, and show clearly that more work is

TABLE II.

Tissue	Average cell area in cm^2/ 10,000	
	Basal Section	Apical Section
Outer cortex	5.6	4.9
Stone cells	10.4	7.3
Inner cortex (including latex vessels)	5.2	4.7
Pith	24.5	11.6
Epidermis	7.4	7.0

needed on this particular topic before it is possible to speak of average "tube bore."

It appears impossible, therefore, to conclude otherwise than that the scientific basis of the theory has not yet been sufficiently established, while opinion seems definitely to indicate that the method has not yet been shown to be suitable for employment on a plantation scale. At the same time consideration should be given to the high cost of the necessary equipment—at least £100—and the fact that this would have to be written off on completion of the planting operation.

The main object of the author in dealing at such length with the Ashplant Method is a secondary but very important one. It serves admirably to illustrate three considerations which should always be in the minds of both planters and research workers. In the first place no planting problem which is amenable to direct experimental attack should be made the object of an indirect statistical attack. In the case of a method of early diagnosis it should be a simple matter to select three lots of plants, good, poor and intermediate, in sufficient numbers to plant up an area which can be test tapped. From the results a reliable conclusion could be gained which would be clear to the working planter.

Secondly, the ultimate criterion of the value of any such method is its profitableness in estate practice. In this connection regard must be had to the initial cost during planting as well as to the increased yield. The former can be worked out in advance but information on the latter point can only come from tapping tests carried out on a sufficiently large scale.

Thirdly, research workers should realize the heavy responsibility incurred in recommending radical departures from established plantation practice on the ground of laboratory experiences or experiments carried out on a small number of trees. If a method is scientifically grounded it can be tested on a plantation scale, while if the same test demonstrates that the method is profitable most of the difficulties associated with the introduction of a new method are overcome at the outset.

In conclusion, attention might be drawn to a new and promising field of investigation in which work has been begun by Kaimal.(4) There is a well-defined latex vessel system both in the embryo and cotyledons of the seed and striking differences are encountered in the seeds of different trees. These are well shown in the hypocotyl region of the embryo where, naturally, they can only be investigated by a destructive test. But similar variations occur in the cotyledons, which can be investigated after the seedling is well-established, and further details of any diagnostic value of these variations will be awaited with interest.

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