IMPROVEMENT IN THE QUALITY OF RUBBER PLANTING MATERIAL*

BY

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Summary

The general principles of the improvement of a perennial crop are briefly discussed and the effect of the improvement of *Hevea* planting material on the position of Malaya as a rubber-producing country is reviewed.

This is followed by an outline of the work of the Rubber Research Institute of Malaya on the breeding and selection of improved planting material during the years 1928-1939.

In the final section it is shown how the results of this work are being applied in practice.

In the discussion on a paper by Ascoli at a meeting of the Institution of the Rubber Industry in 1931, the remarkable advances that had been made in the improvement of the quality of *Hevea* planting material, as a result of the first step in the application to rubber of the orthodox scientific principles of selection and propagation, were stressed. It was pointed out that after a little more than ten years work it had been proved possible to *increase the yields of a first-class rubber plantation from about* 500 pounds per acre to 1,000 pounds per acre. Such an achievement was probably unique in the annals of agricultural or horticultural research on a perennial crop. The discussion futher startled a number of the audience as a calm statement was made that yields of 2,000 pounds per acre would probably be recorded, and that mean yields of 1,500 pounds per acre were expected from young areas then in course of development with the best selected material, principally budded trees of the best proved clones, available at that time. It will be shown that the latter views are well supported by later results and are likely to be fully confirmed in the next few years. The claims, however, met with a somewhat mixed reception. In 1931 all was not well with the rubber plantation industry; overproduction in the face of increasing industrial depression, with no prospects of any expansion in the consumption of rubber, or extension of its uses, led to

*This paper is substantially the same as that read by Mr. Mann at a Meeting of the Institute of the Rubber Industry in London on 11th December 1939 and since published in the Transactions of that Institution (*Trans. I.R.I.* (1940), **XV**, 251) but the data have been brought up to date so as to include results obtained in 1939.

the question: "Why this concentration on improvement in production?" There were many who held the view that science was rendering a positive disservice to the industry, helping to forge a weapon for its ultimate destruction. Such work, it was said, must lead eventually to the collapse of the plantation industry and result in the transfer of the production of raw rubber to the native landowners in rubber-growing countries.

Such extreme views perhaps reflect fairly accurately the disturbed conditions of the commercial world at that time; they also indicate the attitude of mind and the limited view-point which may have been largely responsible for those disturbed conditions. They undoubtedly revealed an inadequate appreciation of the true position.

Amongst those who expressed these views were many people who less than five years before had pressed for the establishment of research institutes for rubber in Malaya and Ceylon. Possibly the outstanding achievements by Dutch planters in the application of agricultural research to tropical cultures, notably to cinchona and sugar cane, and the knowledge that the same course would probably be followed with *Hevea,* aroused fear of a possible repetition in the British rubber-plantation industry of the disastrous effect on the Indian cinchona trade of the signal success of the Netherland East Indies work on the development of this crop.

It was not sufficiently appreciated that research on a perennial crop such as rubber is a relatively slow and laborious business. Plans must be very carefully prepared for a programme of work extending over several years. Such plans inevitably are modified in detail as work advances, but it is generally disastrous to interfere with the main structure of the programme once it has been put into operation. Thus, a few years after work has been done and the first results are available, the conditions within an industry may have changed, as they did in the rubber industry, and the plans which obtained approval initially are severely criticised under the changed conditions. It is indeed fortunate that although the workers in such fields of agricultural research may have to bow to criticism and to transfer their attention to other problems of so-called immediate importance, the material they have developed in accordance with the original plan continues to live and grow. Although their trees may have an unpopular tale to tell at one season, the same tale in a subsequent season may receive a much more favourable reception. The progress of investigations on rubber provide an interesting illustration of that state of affairs.

In 1931 positive proof had just been obtained of the soundness of the methods proposed for increasing the output of a plantation. At that time the application of the results to practice was not far advanced, and the fears that overproduction would be further aggravated were quite unjustified. Even today the entire area planted with high-grade planting material is considerably less than one million acres, and probably does not exceed 10 per cent. of the total planted area of approximately eight million acres. Of the area planted with first-class clones, or clonal seedlings, about 500,000 acres have reached the bearing stage. It will be evident, therefore, that the effect of the scientific development of high-grade planting material will be small at present, and its influence will become effective only gradually as new areas attain and develop from the initial bearing stage. Furthermore, the increase in production from this source is likely to be more than offset by the gradual decline in production and by the replanting of old mature areas, which constitute at least 70 per cent. of the total planted area of 8,000,000 acres.

With the adoption in May, 1934, of the international scheme for the regulation of rubber production, the planting and development of proved material acquired a new and important significance, as the standard of assessment of production of budded areas was almost double that of ordinary plantings made with unselected material.

In the original apportionment of the annual shares of the world's production in 1934 (excluding countries outside the international agreement) Malaya received a lion's share (H.M. Stationery Office, 1938). But, if the changes in the annual apportionment are studied, it will be seen that the position of the Netherland East Indies producers *vis à vis* Malayan producers improves rapidly, so that by the year 1943 the allotment for the Netherland East Indies is almost equal to that of Malaya. No doubt a number of causes contribute to this, but it is certain that one of the most important factors is that the relative proportion of improved material planted in the Netherland East Indies is greater than in Malaya. Incidentally, it would not be surprising to find that if the scale of production were extended beyond 1943, the lion's share would not be allotted to Malaya, for replanting of effete areas with first-class material has been undertaken to a greater extent in Java and Sumatra than in Malaya.

Besides the natural desire to maintain the prestige of Malaya as the first rubber-producing country, there are other and stronger reasons which affect all producing countries equally, and make it imperative that the efficiency of the plantation production machinery should be improved.

During the last ten years great progress has been made in the production of synthetic materials which possess some of the valuable qualities of natural rubber and are free from defects which make the natural product unsuitable for certain uses. The fear of the successful development of a synthetic rubber which may displace the plantation product is of frequent recurrence. The planter hears exaggerated rumours of the imminent large-scale production of a synthetic rubber which has been found to make better motor car tyres than his own plantation rubber.

Ill-founded as these rumours may be, it would be short-sighted to ignore the possibility that new synthetic products may be found which are eminently suited for some of the work for which plantation rubber has hitherto been used. It is, therefore, in the interest of the producer of natural rubber to ensure an ample supply of raw rubber of the right quality, and at a reasonably low stable price, which will make it unnecessary to explore the new synthetic field for a material to replace natural rubber. Further, the producers of plantation rubber may be mistaken in their view that the development of synthetic rubber-like products threatens their industry. The development of these new materials has been the means of introducing rubber to manufacturers who have never used rubber before, and probably the materials feared as competitors may be the means of introducing natural rubber to branches of industry where it has never found favour hitherto.

The relative costs of production of plantation rubber by large estates, European-owned and supervised, and by small estates or holdings, native-owned, constitute a further important consideration. In Malaya about 45 per cent. of a total planted area of three and a quarter million acres consists of Asiatic-owned small estates, and holdings of less than 100 acres each. In the Netherlands East Indies the proportion of Asiatic-owned rubber is rather higher than in Malaya. Such holdings are worked either by the owner and his family or by cheap casual labour, and consequently costs of production are small in comparison with those of the large company-owned estate. It is principally by increasing yield per acre that the large estate can effectively offset the natural advantage of the small owner-producer. In other directions, such as by improving the quality of the product or by the development of special methods of preparation and shipment, the large estate may develop to the full the advantages which the small owner does not possess.

Thus it is seen why the continued study of the improvement in the quality of rubber planting material is of the greatest importance to the industry. It is the job of the scientific worker in agriculture to make two blades of grass grow where only one grew before, and with certain qualifications this is true for our work on *Hevea*. In the next portion of this paper the progress of work on the improvement of *Hevea* will be illustrated by reference to experimental work carried out by the Rubber Research Institute of Malaya since its inception in 1926.

Early Work by the Rubber Growers' Association. Pilmoor Clones

A normal population of *Hevea* trees in the plantation exhibits a wide variation in individual tree form, rate and habit of growth, and also in yield of latex during tapping. The first systematic study of variation in *Hevea* in a Malayan plantation was made by G. S. Whitby (1919), who showed that the outstanding feature of a population grown from ordinary unselected seed was the high coefficient of variability for yield. A detailed examination of a group of about 1,000 trees showed that approximately ten per cent. gave yields of at least double the mean yield of the entire population. The average yield of the trees in this élite group was approximately four times the average yield per tree of the remainder of the population. Actually the yields of the five per cent. of highest yielders were nearly ten times the mean yield of the rest of the population.

These striking findings by Whitby, made in 1918-19, have been confirmed many times. Soon after their publication, Sanderson and Sutcliffe (1928), scientific officers employed by the Rubber Growers' Association in Malaya, carried out a similar investigation on Pataling Estate, and obtained results in 1923 which completely confirmed those obtained by Whitby. At the same time, Sanderson and Sutcliffe selected twenty-one trees of the élite group of the highest yielders, from which they made buddings. The buddings made from Sanderson and Sutcliffe's selected trees were planted in an experimental plot on Pilmoor Estate in September, 1924, and the further study of the clones was taken over by the Rubber Research Institute of Malaya (Botanical Division) in September, 1927.

The buddings of the twenty-one clones had grown satisfactorily, and in January, 1928, it was found possible to commence tapping tests. In view of the tender age of the trees and their value for future investigations, a light tapping system was used during the first year. Since April, 1929, the trees have been tapped continuously, with only three months rest in early 1930, using normal tapping systems of 160 tappings per year on half the circumference of the tree.

Although the mother trees of the twenty-one clones belonged to the élite group of the population from which they were selected, the buddings of all the clones were not of the same desirable quality. In fact, it has been found that only two of the clones can be regarded as first-class; three are of fair value and the remainder are practically worthless, giving yields little better than unselected seedlings; in certain clones yields are inferior to those of the average seedling tree.

TABLE I.

Progress of Growth and Yield of the Pilmoor Clones
January, 1928 to December, 1939
Age of trees 4 years to 15 years

Clone.	No. of trees in 1929 in 1939.	Yield in pounds of dry rubber per tree per year. *Girth in inches at 40 inches from the union* 1928.	1929.	1930.	1931.	1932.	1933.	1934	1935.	1936.	1937	1938.	1939.	Mother tree at age of 7 years. Yield in lb. *Girth (in in.)*
A.44	52	4.4	6.0	6.6	7.1	8.2	9.3	9.5	10.0	10.8	7.0	6.7	7.9	14.8
	37	*18.7*	*19.2*	*20.9*	*23.0*	*24.7*	*25.8*	*27.6*	*28.6*	*29.6*	*30.0*	*31.0*	*32.5*	*42.1*
B.58	29	2.6	4.2	7.2	8.7	10.2	9.6	12.9	14.6	17.3	9.5	11.2	13.6	14.9
	28	*18.2*	*18.8*	*20.4*	*22.0*	*23.2*	*25.3*	*26.7*	*27.5*	*28.1*	*28.6*	*29.5*	*30.2*	*44.0*
B.84	18	3.8	5.2	7.1	9.2	12.3	15.9	18.5	19.2	21.5	17.7	19.4	21.1	10.1
	18	*17.1*	*22.0*	*24.2*	*27.0*	*30.5*	*33.1*	*36.0*	*37.6*	*38.9*	*40.2*	*41.8*	*43.1*	*41.0*
D.65	5	1.7	4.5	11.0	15.9	19.0	20.0	26.0	23.2	23.0	17.6	21.2	22.0	6.4
	4	*16.5*	*20.0*	*26.5*	*30.0*	*31.9*	*33.4*	*36.4*	*37.3*	*39.2*	*39.8*	*41.4*	*42.4*	*33.0*

Notes.—Tapping System and History. *1928.* Test Tapping. C/2, d/2 in alternate months at 20 in. In *May 1929* opened at 36 ins and tapped, alternate daily on half-circumference (C/2, d/2). Tapping has been continuous since then, except for three months rest in early 1930. In *January 1933* turned over to new panel at 40 ins. From *January to July 1935* tapping was on the renewed bark of the 1928 test tapping. In *January 1937* new panel opened 4 ins. above 1929 panel, and renewed bark of that panel reached in *July 1937*. Since then tapping has been on eight-year-old renewed bark.

In Table I the yields of the principal clones are summarised for the period of twelve years, January, 1928, to December, 1939. (*Ann. Rep. Rubber Res. Inst.*, Malaya, 1928—1939). Of the four clones cited in Table I the two clones B84 and D65 may be regarded as fairly representative of the high-grade selected clones which are available for large-scale commercial planting at the present time. The original buddings of these clones have been submitted to the most searching tapping tests, which have been carried out under conditions entirely comparable with those obtaining on a well-run commercial plantation. The trees have been tapped by good Tamil tappers, latex is collected from all trees of each clone and separately bulked by clones, taken to the factory, strained, coagulated and converted into standard smoked sheet, in which form it is weighed and recorded. Incidentally, full data have also been collected on the relative proportions of first-grade and off-grade rubber for each clone, and regular measurements of rate of bark renewal have been taken to supplement the primary data of yield. Also, the Chemical Division of the Rubber Research Institute of Malaya has made detailed investigations on the qualities of the latex and rubber from these clones, and the results have been published in the *Journal* of the Institute. These budded trees have shown no disturbing divergences in their development, they have behaved as normal rubber trees with the important difference that all trees of a clone show little divergence from each other in the steady development of a yield at maturity which is almost treble that of the average seedling tree which was being planted at the time the clones were first established.

These results prove, if further proof be needed, that by the simple application of the methods of selection and vegetative propagation it is possible to produce with certainty, and without limit in practice, large numbers of rubber trees which possess the desirable qualities of uniformity and high yield. In other words, the planter may confine his attention to the first-class material of Whitby's élite group of trees.

Further Proof of Selected Clones

Convincing as these results are to a scientist it is necessary to demonstrate their truth on a larger scale, and for this purpose, as soon as a preliminary selection of the most promising clones had been made, further buddings were planted in large-scale field experiments on estates and on the Institute's Experiment Station at Sungei Buloh. At the same time, similar selected clones obtained from Java, Sumatra and from other sources in Malaya were planted with this material for comparative testing. The

TABLE II.

Comparative Trial of Proved Clones

Field 5. Rubber Research Institute Experiment Station, Sungei Buloh
(Average stand of 100 trees per acre)

Clone.	Percentage tappable trees				Yield of dry rubber (pounds per tree)				Yield of dry rubber (pounds per acre)			
	1936.	1937.	1938.	1939.	1936.	1937.	1938.	1939.	1936.	1937.	1938.	1939.
A.V.R.O.S.49 (Sumatra) ...	63	84	88	91	4.6	6.5	8.9	9.8	290	546	783	892
A.V.R.O.S.152 (Sumatra) ...	59	80	84	89	3.7	4.8	5.9	6.5	218	389	496	578
B.D.5 (Java) ...	18	75	93	95	4.1	5.3	6.6	7.3	74	398	614	693
Tjir.1 (Java) ...	76	89	94	94	7.4	10.2	12.2	13.9	562	908	1,147	1,307
Pil.A.44 (Malaya) ...	75	94	97	99	8.1	9.0	9.5	9.8	608	846	921	970
Pil.B.84 (Malaya) ...	86	98	98	98	5.8	8.5	9.2	10.2	499	833	902	1,000
P.B.186 (Malaya) ...	74	88	99	99	4.9	8.1	9.5	11.2	363	713	941	1,109

Tapping System.—C/2, d/2 commenced at 40 in. from union in January, 1936, when trees were 6 years old from date of planting as budded stumps.

oldest of these "second generation" tests was established in November, 1929, on Field 5 of the Rubber Research Institute's Experiment Station. (*Ann. Rept. Rubber Res. Inst., Malaya,* 1938). The test occupies an area of 40 acres, and every effort has been made in the conduct and control of the experiment to reproduce faithfully good estate conditions. In one respect this has failed; the soil of the experimental area is a poor quartzite sand, well below the average fertility of the normal rubber-estate soil of the country. For comparative trials this may not be altogether a disadvantage, but it should be borne in mind, when studying the data in Table II, that the figures are of essentially comparative value. If absolute values are required, then such an experiment must be repeated on a number of different soil types.

The Pilmoor clones A44 and B84 compare well with the other clones selected as the best from all sources at the time when the experiment was commenced. Clone Tjir. I is outstanding, and indeed this clone has surpassed all others of similar origin in the large number of trials from which yield records are available. Yields of 1000 to 1100 pounds per acre (on a poor soil) must be regarded as satisfactory for trees in their tenth year of age.

Breeding of New Seedling Families from Proved Clones

Another important method whereby the quality of a crop may be improved is by selecting seeds only from the best parent trees. This method has received equal attention with the vegetative method, but, from the nature of the work involved, progress is much less rapid. Early investigators planted seeds carefully collected from the highest-yielding mother trees, whose value as individual high producers had been established; in many cases the same trees were used as the bud-parents of clones. When young areas planted with these seeds reached the bearing stage it was found that their average yields were from 18 to 36 per cent. higher than those of unselected seedlings. This result was disappointing; a greater improvement was expected, but the reason for the comparative failure was not far to seek. In the ordinary plantation of unselected seedling trees, good and bad trees are neighbours. When flowering takes place the flowers on a high-yielding mother-tree may be fertilised by pollen from a poor father-tree, and the resulting progeny may show a wide range of characters from good to bad, and certainly the largest proportion will not be better than mediocre.

The rubber tree, *Hevea brasiliensis,* bears flowers of two kinds, male flowers on the finer branches and female flowers at the tips of the stronger branches of the same flower spray. Pollination in the Amazon valley, the native habitat of *Hevea,* appears to be effected by a species of bee. Apparently this species is not found in the East Indies, where considerable doubt still exists concerning the identity of the insect or other agents responsible for effecting pollination in rubber. Careful experiment has shown that the majority of *Hevea* trees are selfsterile, that is to say, fertilisation and the development of perfect seeds rarely occurs unless pollen is carried from one tree to the female flowers of another tree. This process is known as cross-pollination, or more briefly, crossing. This helped to explain the disappointing results obtained from the simple collection of seeds from high yielders, and led to the investigation of methods of artificial pollination or crossing between selected parent trees.

In 1928 investigations were commenced on this subject at Kuala Lumpur. Already the tapping experiments on the Pilmoor clones had given valuable information and had provided promising parent material in the young budded trees of such clones as those included in Table I. It is a fortunate characteristic, from the plant breeder's point of view, that young budded trees are inclined to flower early and may set perfect seeds even at the early age of three years. At this age the trees are small, and it is quite easy, by using light scaffolding or portable platforms, to work on the flowers in comparative ease and comfort, both of which are important factors influencing success under tropical conditions. After preliminary work in 1928, large programmes of crossing were carried out from 1929 to 1931, when the work was suspended owing to slump conditions and staff reductions, until 1937.

The technique of crossing, in *Hevea,* has been described by L. E. Morris (1928).

The Technique of Cross-Pollination

A typical flowering branch is shown in Fig. 1. The first step in preparing a branch for pollination is to remove all the male flowers and all the female flowers that have opened, and to leave on the branch only those female flowers that are mature but of which the perianth has remained closed. (Fig. 2). The pollinator then forces apart with a pair of forceps the petals of the female flowers (Fig. 3) and places inside the petals the staminal columns which he has previously removed from a male flower of the tree to be used as a father (Fig. 4). To keep the staminal column in position and to prevent uncontrolled natural pollination taking place the flower is closed with a plug of cotton wool or *kapok* which is kept in place with a small drop of latex (Fig. 5). After about five months the fruits, which normally contain three seeds each, are ready for harvesting. (Fig. 6). Success on the scale illustrated in Fig. 6 is regrettably rare.

FIG. 1. Complete inflorescence.

FIG. 2. Removing male flowers and opened female flowers.

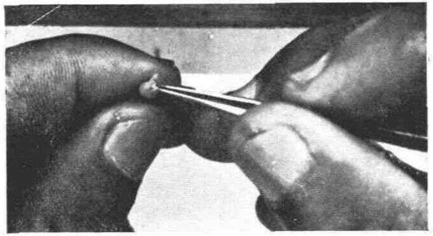

FIG. 3. Opening female flower.

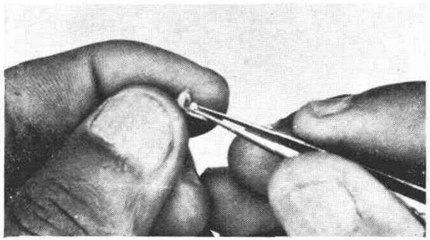

FIG. 4. Inserting stamens.

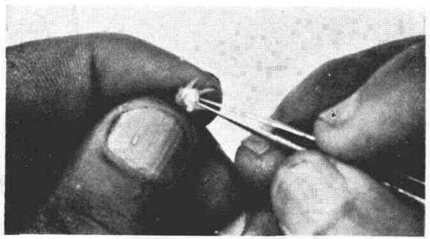

FIG. 5. Plugging female flower.

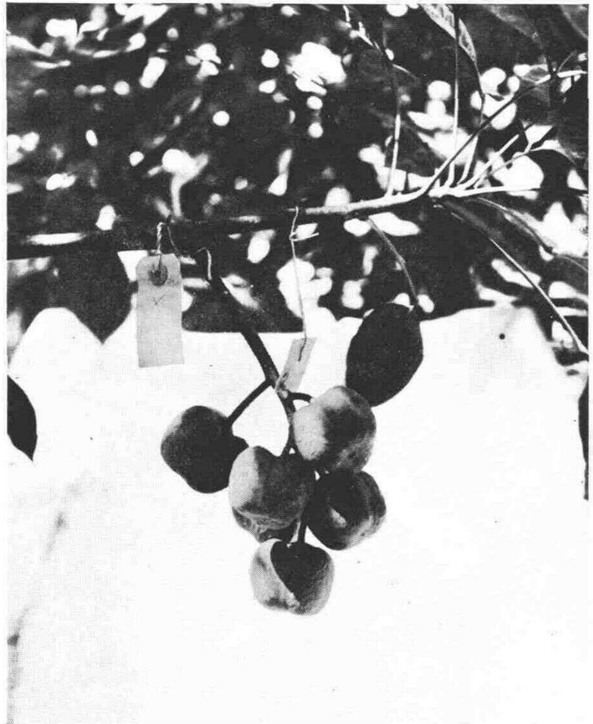

FIG. 6. Ripening fruits.

An exceptionally successful result.

The seedling crosses obtained from the Pilmoor clones were planted on the Experiment Station. For convenience the seedlings obtained by careful hand-pollination are called legitimate seedlings, for both parents are known with certainty and their union has been blessed, or otherwise distinguished, by the plant breeder. From the parent trees seeds were also collected which had developed naturally, and these are called illegitimate seeds, only the mother-parent being known with certainty. For subsequent comparison the legitimate seedlings, illegitimate seedlings and ordinary unselected seedlings were planted together in the same plots. A full account of this work during the years 1928 to 1938 has been given by Sharp (1940).

TABLE III.

GROWTH AND YIELD OF LEGITIMATE, ILLEGITIMATE AND UNSELECTED SEEDLINGS

Planted October—November, 1929. (Compare Table II.)

Family of seedlings	No. of trees	Yield of rubber (pounds per tree per year) *Girth (inches at 40 inches from ground)* 1935.	1936.	1937.	1938.	1939.
B.84.A.44 -	32	6.1	9.5	13.3	14.4	17.3
		22.8	*25.0*	*27.0*	*28.2*	*29.8*
B.58.A.44 -	27	4.7	7.3	11.3	11.1	12.7
		16.0	*18.0*	*20.1*	*21.4*	*23.0*
B.58.B.84 -	15	5.7	8.3	10.8	14.4	20.8
		17.5	*18.9*	*21.4*	*23.1*	*24.6*
A.44 (Illeg.) -	67	3.8	5.9	8.8	9.2	12.8
		19.8	*22.3*	*24.3*	*26.2*	*27.8*
B.84 (Illeg.) -	157	4.0	7.0	10.5	11.0	15.8
		19.4	*22.2*	*24.7*	*27.3*	*29.1*
B.58 (Illeg.) -	70	2.9	5.0	7.5	7.5	11.2
		18.5	*21.2*	*23.4*	*25.5*	*27.0*
Unselected seedlings -	244	1.4	2.3	3.8	3.6	5.9
		13.8	*17.4*	*20.3*	*23.0*	*25.0*
Buddings. Tj.1 -	300	—	7.4	10.2	12.2	13.9

Tapping tests on these seedling collections were commenced in January, 1935, and in Table III representative results are presented. In order to provide a rough basis of comparison the records have been quoted for the families of seedlings planted in November, 1929, that is at about the same time as the buddings described in the preceding section which were planted in Field 5 (see Table II). The two fields containing buddings and the seedling crosses are on very similar soil, and are practically adjacent to each other. Strict comparison is not possible, but the differences in environment and treatment of the two fields are quite small. In Table IV further records of the yields of several plantings of the same family of seedlings, obtained by crossing in successive flowering seasons, are also summarised.

TABLE IV.

YIELD AND GROWTH OF LEGITIMATE SEEDLINGS OF THE FAMILY B84. A.44 OBTAINED BY HAND POLLINATION IN SUCCESSIVE SEASONS

Date of planting	No. of trees	Yield of rubber (pounds per tree per year) *Girth (inches at 40 inches from ground)* 1935.	1936.	1937.	1938.	1939.
April, 1929 -	8	8.9	12.6	16.1	16.4	21.2
		26.6	*29.0*	*31.2*	*32.6*	*34.5*
October, 1929 -	32	6.1	9.5	13.3	14.4	17.3
		22.8	*25.0*	*27.0*	*28.2*	*29.8*
April, 1930 -	36	5.8	7.1	10.2	13.2	17.5
		17.6	*20.6*	*23.4*	*25.3*	*27.0*
November, 1930 -	47	—	5.6	9.9	9.7	11.1
			20.2	*23.6*	*25.3*	*27.8*
-	46	—	5.1	8.5	9.3	11.6
			19.9	*23.2*	*25.0*	*27.7*

Note.—In the November, 1930 Series, 47 trees are of the cross A44×B84 where A44 is the mother and 46 trees of the cross B84×A44 with B84 as the mother parent.

The yields of the legitimate seedling families are excellent. The best two families, both of which have B.84 as one of the parents, give average yields which exceed those of budded trees of the best clone, Tjir. I, in Field 5. The yields of the illegitimate seedlings of the three parent clones, from which results are quoted, are also satisfactory. Comparing the yields of these clonal seedlings with those of ordinary unselected seedlings grown under identical conditions, it is found that the legitimate seedlings give as much as four times the yield of the unselected seedlings; the illegitimate seedlings, of clone B.84 for example, give about three times the yield of the unselected seedlings.

The records summarised in Table IV show that crossing between the two parents A.44 and B.84 in successive flowering seasons has given seedlings of the same value, and the results obtained with the first small family of eight seedlings have been confirmed fully by the larger families raised in subsequent seasons.

The "second string" in the improvement programme has proved as successful as the first, but there are important differences in the material obtained by the two methods of attack, the one on vegetative and the other on generative lines.

Comparison of Buddings and Legitimate Seedling Families

The budded trees of a single clone show a high degree of uniformity in habit, growth and yield. This makes it possible to work out the best methods of treatment for each clone. The best clone for a given soil type or situation can be chosen, and by experiment the best tapping system to apply. Later it may be discovered that the properties of the latex and of the rubber obtained from a particular clone may differ in some manner from the mixed product obtained from a seedling plantation, and it is not improbable that unique qualities may be discovered which may be of considerable practical importance.

In a family of seedlings derived from two parents, although the variability in the characters of the offspring is less than that encountered in a mixed population of unselected seedlings, it is, nevertheless, quite considerable. For example, in the family A.44 × B.84 planted in 1929, the lowest-yielding tree gave less than 10 pounds of dry rubber in its fourth tapping year, whereas the highest-yielder gave well over 50 pounds of dry rubber in the same year. Thus, although high average yields are obtained, the disturbing factor of high variability is still present, with all its attendant disadvantages in practice.

There is another important consideration; once a clone has been established and its superior value proved by adequate tapping tests, it is ready for use. It is a simple matter to prepare supplies of budwood in a short period and to distribute such supplies to estates for further multiplication in readiness for the time when the clone can be planted with confidence on a large scale.

On the other hand, even when the value of a legitimate seedling family has been proved, the problem of obtaining sufficient seeds of the same parentage for large-scale planting has still to be solved. A considerable period must elapse before large quantities of seed of the valuable crosses can be obtained.

In another direction the variability encountered within a high-yielding family of seedlings provides a very valuable means of further advance in the improvement of the material. The highest-yielding and otherwise satisfactory individuals of a family should make valuable mother-trees of new clones, and in the following section this will be considered.

NEW CLONES FROM LEGITIMATE SEEDLINGS

The writer has always inclined to the view that a combination of the vegetative and generative methods, using them in a complementary rather than in a divergent manner, offers the best possibility of success from the practical viewpoint of improvement of *Hevea* planting material.

TABLE V.

YIELDS OF SOME NEW CLONES DERIVED FROM LEGITIMATE SEEDLINGS

R.R.I. Clone No.	Origin of mother tree		Yield of dry rubber (pounds per tree per year)				
			1935.	1936.	1937.	1938.	1939.
500	B84 × A44	...	5.6	13.1	15.9	17.9	21.0
501	A44 × Lun N.	...	—	9.3	18.2	26.3	25.1
502	B16 × A44	...	3.8	9.1	8.7	13.5	18.8
505	A44 × Lun N.	...	—	7.1	10.4	13.6	16.4
506	B84 × A44	...	—	7.6	13.8	16.1	22.5
511	A44 × B16	...	—	8.1	13.3	14.2	16.9
513	B16 × A44	...	—	8.0	19.2	16.5	15.0
514	A44 × B58	...	—	7.1	14.6	15.1	17.6
515	A44 × D61	...	—	6.4	13.9	17.0	19.9
518	D61 × A44	...	—	5.2	11.4	13.5	12.3

Note.—Clones 500 and 502 were budded in November, 1930. All other clones were budded in October—November, 1931. Taiping was commenced when the trees were just four years old.

Accordingly, as soon as the seedling crosses, some of which have been described above, were one year old, from 6 to 10 dormant buds from each one were budded on one- to two-years-old seedlings in other experimental plots. Thus, even before the value of a seedling was known, clones were made from it, and nearly 1,000 new clones were established in this way. By this means a great saving in time was effected, for the buddings reached the tapping stage almost as soon as the young mother-trees from which they were derived. Of the new clones over 500 have been tapped for a period of three years or more and from these has been selected a group of above 20 new clones, some of which, on their early records, promise to be superior to the best of the older clones at present in use.

In Table V are summarised the yield records of a number of the new clones, which for convenience are named the R.R.I. 500 Series. Clones 500 and 501 are of outstanding promise, and the remainder show yields equal to or better than those of clones Tjir. I and Pilmoor B.84, which are the best yielders of the older group of clones under trial in Field 5 (Table II). During 1938 and 1939 large-scale field trials of these new clones have been established in blocks of 25 to 50 acres on ten estates in different parts of Malaya.

Summary of Investigations

The principal results of the work can be conveniently discussed in reference to Table VI. and Fig. 7. The three main advances since the selection of the original mother-trees by Sanderson and Sutcliffe on Pataling Estate, are illustrated by reference to the results of tapping tests on the clones, the seedlings derived from them by artificial and normal pollination, and promising new clones developed from these seedlings.

The principal results may be summarised thus:—

(1) From selected mother-trees of an ordinary field of seedlings, *Hevea* clones have been developed and proved capable of yields almost treble the average of the population from which the mother-trees were chosen.

(2) By breeding between these clones, families of seedlings have been obtained whose mean yields are greater than those of the clones from which they were derived.

(3) The illegitimate seedlings from the best parent clones may give yields which are not appreciably inferior to those of their parents.

(4) From outstanding individual trees of the legitimate seedling families, new clones have been made whose yields may be double those of the original clones from which they have been derived.

Fig. 7 PROGRESS OF SELECTION AND BREEDING

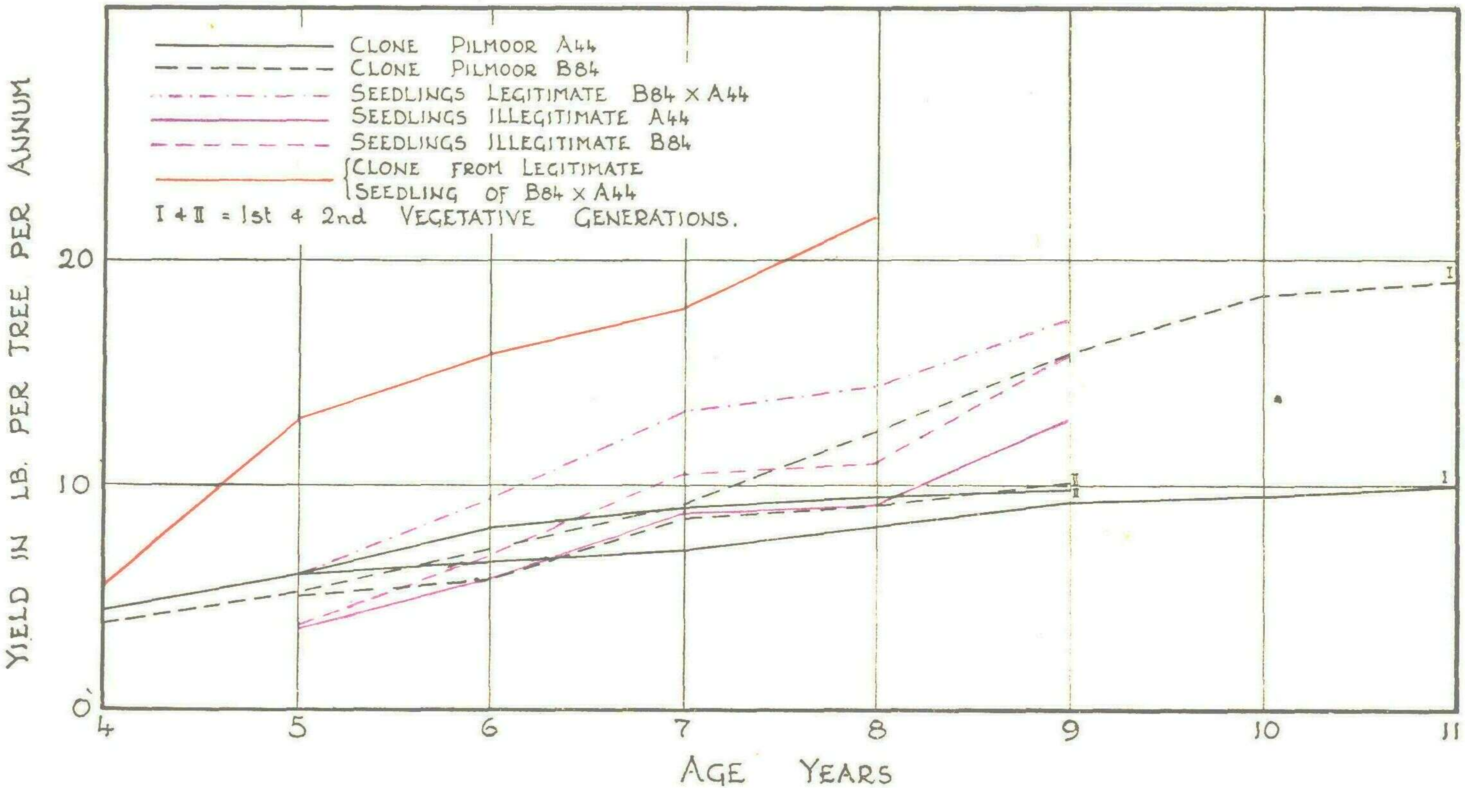

TABLE VI.

RESULTS ILLUSTRATING THE PROGRESS OF SELECTION AND BREEDING WORK

		Yield of dry rubber (pounds per tree per year) at ages in years—							
Stage	Material	4.	5.	6.	7.	8.	9.	10.	11.
I. Proof of Clones.	*Original buddings.*								
	Clone B84.	3.8	5.2	7.1	9.2	12.3	15.9	18.5	19.2
	„ A44.	4.4	6.0	6.6	7.1	8.2	9.3	9.5	10.0
	"Second Generation" Buddings.								
	Clone B84.	—	5.0	5.8	8.5	9.2	10.2	—	—
	„ A44.	—	6.0	8.1	9.0	9.5	9.8	—	—
II. Breeding of Seedling Families.	*Legitimate Seedlings.*								
	B84 x A44.	—	6.1	9.5	13.3	14.4	17.3	—	—
	Illegitimate Seedlings.								
	B84.	—	4.0	7.0	10.5	11.0	15.8	—	—
	A44.	—	3.8	5.9	8.8	9.2	12.8	—	—
III. New Clones from Crosses.	*Original Buddings.*								
	Clone R.R.I. No. 500. (B84 x A44)	5.6	13.1	15.9	17.9	21.0	—	—	—

APPLICATION OF RESULTS TO PRACTICE

The proved Pilmoor clones B.84 and D.65 have already been planted extensively in Malaya and also in Java and Sumatra. It is interesting to note that clone Pilmoor B.84 is now universally recommended for large-scale planting. Independent tests of the clone carried out by the Algemeene Vereeniging van Rubber-planters ter Oostkust van Sumatra and by the Proefstation in West Java have yielded results, over a period of five years, which are almost identical with the results obtained in Malaya.

The immediate application to practice of the results of breeding of high-yielding seedlings is limited by the difficulty of producing sufficient seeds of the same origin for large-scale planting. However, various means have been employed to supply seeds of superior origin for commercial planting.

Buddings of high-yielding clones have been planted in areas isolated as completely as possible from other rubber plantations. At the same time, breeding experiments have been carried out between the various clones used in the isolated gardens, in order to discover the most valuable parents. From the results of tapping tests on the small seedling families the best parent clones are revealed, and inferior parents can then be eliminated from the seed garden. Seeds obtained from such gardens have already been planted on a large scale. Although their value cannot be regarded as fully proved at present, it is reasonably certain that plantings made with such material will give satisfactory yields.

A further development of breeding work has been vigorously pressed forward by a few enterprising estates, principally in the Netherlands East Indies. Artificial pollination is being carried out on a large scale with trained coolie labour; one estate near Batavia produced over 300,000 legitimate seeds of a number of families of proved value during the 1938 flowering season.

In the past three years many estates on which replanting is in progress have taken the opportunity to establish potential seed-production areas in their young replantings. In fields of 50 acres or more, planted on the monoclone system with the best-known proved clones, areas of 10 acres or more, centrally situated, are planted with two or more clones known to be valuable parents. Pollination between these parents will produce large quantities of valuable seed for future use if required. The wide belt of budded trees of a first-class clone surrounding the central seed-production area, provides an effective barrier against the entry of pollen from inferior trees.

The excellent yields of the illegitimate seedlings of some of the parent clones used in breeding work has resulted in a considerable amount of replanting with illegitimate clonal seedlings. The use of such material is not advised on more than an experimental scale; the risk of disappointment is too great and, moreover, such risk is not justified when planting with the best proved clones will ensure future yields which are at least equal to and probably superior to those of all the illegitimate seedling families which have been tested so far.

But the protagonists of buddings have met with stubborn criticism from the outset, and there are many planters who still frankly prefer the natural seedling tree to the so-called unnatural budgraft. It is outside the scope of this paper to discuss all the pros and cons of buddings and clonal seedlings, but the strong tendency in some quarters to incur unnecessary risk by abandoning too soon the planting of proved buddings, in favour of insufficiently proved clonal seedlings cannot be too strongly deprecated.

With regard to the use of new clones developed from crosses, considerable numbers of these clones have already been distributed and established in experimental areas on estates. These clones will be the planting material of the future when the older clones will have proved their worth on the plantations and the wave of enthusiasm for clonal seedlings has subsided.

Investigations are being continued. From the clones of the R.R.I. "500-Series" a selection of the best types was made for further breeding work. New crosses have been made between them and also with the best of the older proved clones from all sources. From the new families new clones have again been made from most of the individual crosses, and within three years the results of the next step in the programme will be available.

In conclusion, the writer wishes to acknowledge the work of his colleagues of the Botanical Division of the Rubber Research Institute. The early work on the Pilmoor clones was carried out by the writer and Dr. E. Rhodes. Mr. K. N. Kaimal has been responsible for the greater part of the recording work on those clones during the past eight years. Mr. L. E. Morris carried out the early programme of breeding work until the end of 1931. Since that time, Mr. C. C. T. Sharp has continued this work and has been responsible for the subsequent testing and selection of seedling families and new clones from crosses.

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