Progress of Breeding Investigations with Hevea brasiliensis III. Further Data on the Crosses Made in the Years 1937–1941

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The results up to 1961 of the trials with seedlings bred in the years 1937 to 1941 are presented, discussed and compared with those up to 1950 presented by SHARP *(1951).*

Doubt is expressed as to the validity of Sharp's conclusions regarding inbreeding depression.

The conclusions regarding the best parents are the same as Sharp's and it is suggested that careful interpretation of the records for yield, and girth and incidence of dry trees is sufficient to make possible the recognition of the best seedling families and the best parents after five years of tapping.

Breeding and selection of *Hevea brasiliensis* was started at the Rubber Research Institute of Malaya in 1928, and has continued each year since then, except for interruptions caused by the economic depression (1933—1936) and the Second World War (1942—1946).

A summary of breeding done from 1928 to 1963 was prepared by Ross (1964) who subdivided the work into phases as follows:

Phase I — 1928–1932, Series 1–7
Phase II — 1937–1941, Series 8–12
Phase III — 1947–1958, Series 13–24
Phase IV — 1959–1963 and continuing, Series 25–29

SHARP (1940) reported the results of the breeding programmes carried out during Phase I; no further data are available on this phase.

The results up to 1950 of the breeding programmes carried out during Phase II have also been reported by SHARP (1951). The object of this paper is to present data of particular interest which have become available since 1950 concerning some of the seedling families produced during Phase II.

In the trials described here, seedlings produced by hand pollination were compared in order to assess the value of the parent clones when used in various combination in seed gardens. Buds were also taken from the seedlings and used for grafting in small-scale clone trials for the eventual selection of new clones, but this aspect of the breeding and selection programme is not discussed in this paper.

CALCULATION OF YIELDS

Before considering the yield records of the seedling families produced during Phase II, it is necessary to explain certain difficulties which have been encountered in their interpretation. The seedlings were all tapped (S/2.d/2.100%) on a half-spiral cut every alternate day, an arbitrary intensity of 100% instead of the 67% recommended for seedlings in commercial practice and, as a result, a high proportion of trees became dry. The yield records published by SHARP (1951) were expressed as pounds per tree per year assuming 160 tappings per year, but the calculations were based on actual tappings only. In other words, the mean weight per tree of cup coagula from each family was calculated and then multiplied by 160 to give

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the mean yield per tree per year. If a tree became dry during the year only the tappings which resulted in cup coagula were taken into account. The result is that Sharp's yield records do not take dry trees into account and the value of a seedling family which has a high proportion of dry trees is much exaggerated. Sharp did report the percentage of dry trees in each family but this can be misleading in the assessment of the relative value of the families, as will be shown below.

If the yields per tree per year are calculated by taking into account all tappings which should have taken place during the year, a mean yield per tree for each family is obtained which reflects the effect of dry trees on the value of the family. For example, if a tree was dry for six months of the year and yielded 0.125 lb per tapping during the remaining six months, the yield per tree per year would be given as 10 lb $(0.125 \times \frac{160}{2})$ not as 20 lb as it would be according to Sharp's method of calculation.

In the tables presented in this paper, yields calculated by both methods are given. The value of the yields calculated by Sharp's method is that they allow comparison between the families on their relative yield potential assuming no dry trees. In commercial practice the seedlings would have been tapped S/2.d/3.67% which would have resulted in a much lower incidence of dry trees.

The method of calculation which Sharp used will be referred to as 'method 1' and the other, taking dry trees into account, as 'method 2'.

YIELD AND GIRTH RECORDS

1937 HAND-POLLINATED SEEDLINGS, SERIES 8

In 1937, Tjir 1, AVROS 157 and Pil B84 were chosen as main parents and were crossed with seven subsidiary parents PB 186, PB 86, PB 49, PB 24, BD 5, Gl 1 and AVROS 33. After five years of tapping, Sharp (1951) concluded that Tjir 1 was on the average a better producer of high-yielding seedlings than Pil B84 and that it might also be superior in this respect to AVROS 157 which in turn might be better than Pil B84, although this was not demonstrated.

In 1960 the fifteenth year of tapping was completed and examination of the yield records leads to conclusions which differ slightly from those of Sharp. In the present comparison the families of which PB 186 and AVROS 33 were parents have been omitted because of the small number of seedlings in some of them.

Yields

The yields, calculated by both methods, for the first five years of tapping, for the ten-year period from the sixth to the fifteenth year of tapping and for all fifteen years of tapping are given in *Table 1* and shown graphically in *Figure 1*.

Main parents. Over the first five years of tapping the yields of the Tjir 1 and AVROS 157 seedlings, calculated by method 1, only just failed to be significantly higher than those of Pil B84 at $P=0.05$. When calculated by method 2, the yields of both the Tjir 1 and the AVROS 157 seedlings were significantly higher than those of Pil B84.

During the period from the sixth to the fifteenth year of tapping the yields of the AVROS 157 seedlings were significantly higher than those of both the Tjir 1 and the Pil B84 seedlings, irrespective of the method of calculation.

Over the whole period of fifteen years the AVROS 157 seedlings were significantly higher yielding than the Pil B84 seedlings when the yields were calculated by method 1. When method 2 was used the Tjir 1 seedlings were also significantly higher yielding than the Pil B84 seedlings.

Subsidiary parents. When the yields were calculated by method 1, the PB 49 and PB 24 seedlings were significantly higher yielding over the first five years of tapping than those of Gl 1, PB 86 and BD 5, but when they were calculated by method 2 the PB 49 seedlings were also significantly superior to the PB 24 seedlings, which were then superior only to the Gl 1 and PB 86 seedlings.

During the period from the sixth to the fifteenth year of tapping and over the whole fifteen years' period the PB 24 and PB 49 seedlings yielded significantly more than those of PB 86, Gl 1 and BD 5 irrespective of the method of calculation used.

TABLE 1. 1937 HAND-POLLINATED SEEDLINGS, SERIES 8. MEAN YIELDS OF BULKED FAMILIES OF MAIN AND SUBSIDIARY PARENTS IN LB PER TREE PER ANNUM

(M.S.D.=min. 5% significant difference between means, assuming common s.e.'s. >=greater than, at 5% significance level or less)

Parents		Period of tapping, years	Method 1	Method 2	M.S.D.
Main	A Tjir 1	1 - 5	14.10	13.24> C	
		6-10	16.82	15.24	
		1-15	15.72	14.34> C	
	B AVROS 157	1 - 5	13.92	13.42> C	1 - 5 years: 2.35
		6-10	19.68> AC	18.44> AC	6 - 10 years: 2.85
		1-15	17.78> C	16.60> C	1 - 15 years: 2.67
	C Pil B84	1 - 5	11.92	10.54	
		6-10	15.28	13.24	
		1-15	13.76	11.64	
Subsidiary	D PB 86	1 - 5	11.23	10.47	
		6-10	13.63	11.47	
		1-15	12.60	10.83	
	E PB 24	1 - 5	15.53> DGH	13.70> DG	
		6-10	22.10> DGH	19.97> DGH	
		1-15	19.57> DGH	17.30> DGH	
	F PB 49	1 - 5	17.53> DGH	16.90> DEGH	1 - 5 years: 3.03
		6-10	21.83> DGH	20.30> DGH	6 - 10 years; 3.68
		1-15	20.50> DGH	19.13> DGH	1 - 15 years: 3.46
	G Gl 1	1 - 5	10.37	9.77	
		6-10	15.23	14.00	
		1-15	13.23	12.03	
	H BD 5	1 - 5	11.90	11.17	
		6-10	13.50	12.47	
		1-15	12.87	11.67	

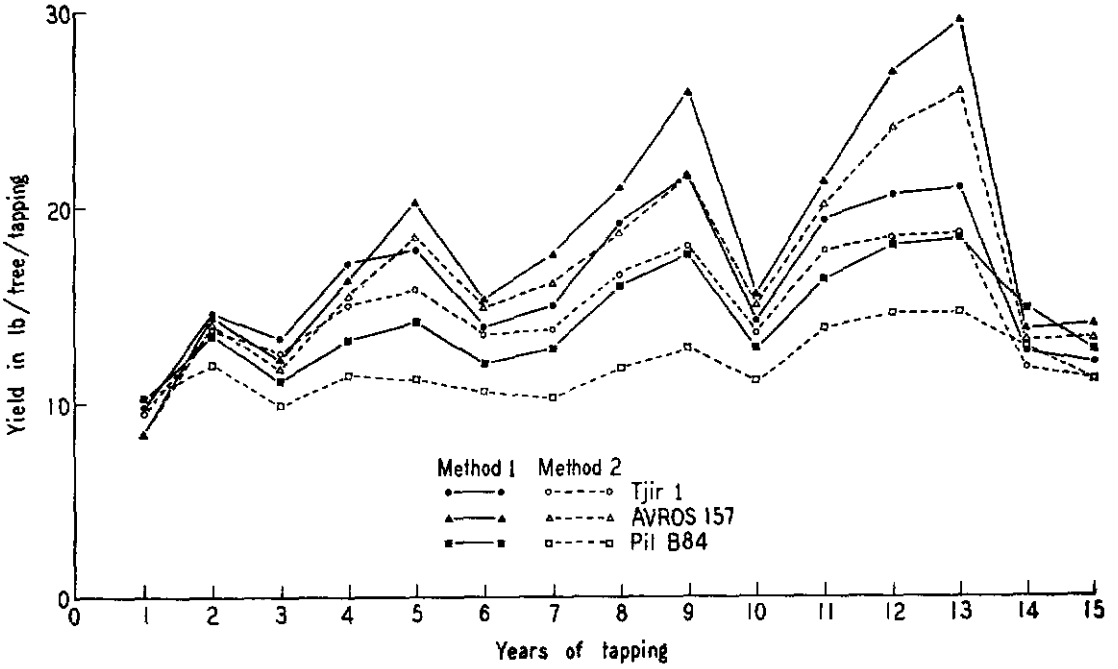

Figure 1. Mean yield of seedlings of AVROS 157, Tjir 1 and Pil B84 each crossed with PB 86, PB 24, PB 49, Gl 1 and BD 5.

Individual families. The four highest-yielding families were AVROS 157×PB 49 and × PB 24, and Tjir 1×PB 49 and×PB 24. The lowest-yielding families are the result of crosses of Tjir 1×PB 86 and×Gl 1, and Pil B84×PB 86 and×Gl 1. Significant differences between the individual families are shown in *Table 2.*

Girth

The girths of the bulked families are given in *Table 3.* Girths are affected by the incidence of dry trees because dry trees tend to grow faster than those that are tapped, but this is not sufficient to upset comparisons. It is not possible to omit trees which were affected by dryness because they form a large proportion of the total.

Main parents. When measured in 1946, the mean girth of the AVROS 157 families was very nearly significantly greater than that of the Pil B84 seedlings at P=0.05. The Tjir 1 seedlings were intermediate. Nine years later, in 1955, the mean girth of the AVROS 157 seedlings was significantly greater than that of both the Tjir 1 and Pil B84 seedlings between which there was no significant difference.

Subsidiary parents. In both 1946 and 1955 the mean girth of the PB 49 seedlings was significantly greater than the mean girths of the PB 24, BD 5, PB 86 and Gl 1 seedlings. The mean girth of the PB 24 seedlings was significantly greater than that of the Gl 1 seedlings in 1946 and that of the BD 5 seedlings in 1955.

Individual families. The girths of the individual families are given in *Table 4.* The most vigorous families are PB 49×AVROS 157× Tjir 1 and×Pil B84. The least vigorous families are: Tjir 1×PB 86 and×BD 5; and Pil B84×PB 86 and×BD 5. Significant differences between the families are also shown in *Table 4.*

Dry Trees

The Pil B84 seedlings had higher proportion of dry trees than the Tjir 1 and AVROS 157

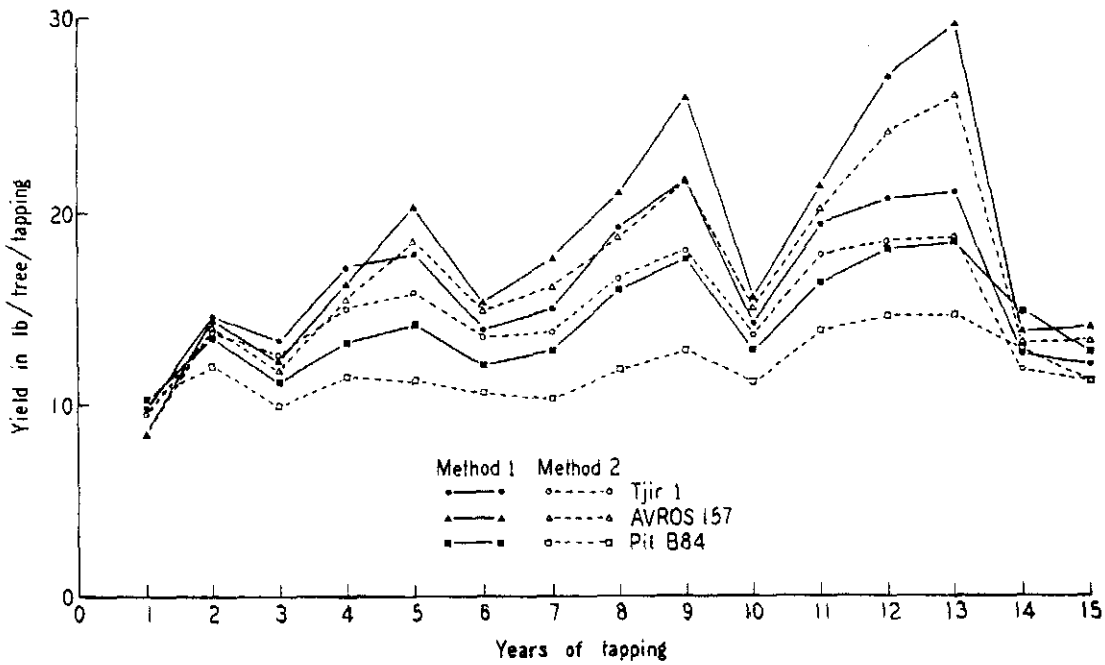

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TABLE 2 1937 HAND-POLLINATED SEEDLINGS SERIES 8 INDIVIDUAL FAMILIES YIELD IN LB PER TREE PER ANNUM

	Families	No of trees	Mean yield over first 5 years of tapping				Mean yield from 6th to 15th year of tapping				Mean yield over 15 years of tapping			
			Method 1		Method 2		Method 1		Method 2		Method 1		Method 2	
			Yield	Families or parents with means inferior at 5% sig or less	Yield	Families or parents with means inferior at 5% sig or less	Yield	Families or parents with means inferior at 5% sig or less	Yield	Families or parents with means inferior at 5% sig or less	Yield	Families or parents with means inferior at 5% sig or less	Yield	Families or parents with means inferior at 5% sig or less
A	Tjir 1×PB 86	63	10 8±0 73		10 2±0 71		11 8±0 99		10 3±0 96		11 3±0 85		10 1±0 76	
B	Tjir 1×PB 24	26	17 7±1 81	$\{AA_1A_2DD_1D_2 \atop EE_1E_2$	16 1±1 72	$\{AA_2B_2DD_1D_2 \atop E_1E_2D$	23 4±2 13	$\{AA_2DD_2EE_1 \atop E_2$	21 4±2 11	$\{AA_1A_2C_2DD_2 \atop EE_1E_2$	21 5±1 90	$\{AA_1A_2C_2DD_1D_2 \atop EE_1E_2$	19 7±1 85	$\{AA_1A_2B_2C_2DD \atop EE_1E_2$
C	Tjir 1×PB 49	44	20 6±1 19	$\{AA_1A_2B_1B_2C_2 \atop DD_1D_2EE_1E_2$	19 8±1 22	$\{AA_1A_2B_1B_2C_2 \atop DD_1D_2EE_1E_2$	22 0±1 74	$\{AA_2DD_2EE_1 \atop E_2$	21 0±1 80	$\{AA_1A_2C_2DD_2 \atop EE_1E_2$	21 9±1 35	$\{AA_1A_2C_2DD_1D_2 \atop EE_1E_2$	20 5±1 40	$\{AA_1A_2B_2C_2DD \atop D_2EE_1E_2$
D	Tjir 1×Gl 1	27	10 4±1 27		9 6±1 23		15 2±2 49		11 8±1 88		13 0±1 75		10 7±1 47	
E	Tjir 1×BD 5	5	11 0±1 84		10 5±2 30		11 7±3 19		11 7±3 19		10 9±2 83		10 7±2 82	
	Mean I		14 1		13 2	III	16 8		15 2		15 7		14 3	III
A_1	AVROS 157×PB 86	55	13 0±1 00	A_2	12.5±1 02	A_2	17 8±1 82	AA_2	15 3±1 81	AA_2	16 0±1 40	AA_2	14 1±1 41	AA_2
B_1	AVROS 157×PB 24	18	15 1±1 56	AA_2DD_2	14 6±1 65	$AA_2B_2D_2$	21 7±2 81	$AA_2D_2EE_2$	20 3±2 99	AA_2DE_2	19 5±2 29	$AA_2DD_2EE_2$	18 4±2 41	AA_2DD_2EE E
C_1	AVROS 157×PB 49	48	17 7±1 14	$\{AA_1A_2B_2C_2 \atop DD_1D_2EE_1E_2$	17 4±1 13	$\{AA_1A_2B_2C_2 \atop DD_1D_2EE_1E_2$	25 9±1 87	$\{AA_1A_2C_2DD_1 \atop D_2EE_1E_2$	25 0±1 85	$\{AA_1A_2C_2DD_1D_2 \atop EE_1E_2$	23 2±1 52	$\{AA_1A_2C_2DD_1D_2 \atop EE_1E_2$	22 5±1 50	$\{AA_1A_2B_2C \atop DD_1D_2EE_1E_2$
D_1	AVROS 157×Gl 1	16	11 0±1 50		10 8±1 56		17 4±2 78		17 1±2 81	AA_2	15 4±2 27		15 1±2 29	AA_2
E_1	AVROS 157×BD 5	21	12 8±1 25		11 8±1 15		15 6±1 67		14 5±1 61	AA_2	14 8±1 43		12 9±1 26	A_2
	Mean II		13 9		13 4	III	19 7	I, III	18 4	I, III	17 8	III	16 6	III
A_2	Pil B84×PB 86	32	9 9±1 00		8 7±1 03		11 3±1 82		8 8±1 55		10 5±1 33		8 3±1 23	
B_2	Pil B84×PB 24	24	13 8±1 33	A_2D_2	10 4±1 17		21 2±4 14	AA_2	18 2±3 33	AA_2	17 7±2 86	AA_2	13 8±2 26	A_2
C_2	Pil B84×PB 49	37	14 3±0 95	AA_2DD_2	13 5±0 91	$AA_2B_2DD_2$	17 6±2 08	AA_2	14 9±1 57	AA_2	16 4±1 35	AA_2	14 4±1 22	AA_2
D_2	Pil B84×Gl 1	6	9 7±1 40		8 9±1 87		13 1±2 37		13 1±2 37		11 3±1 90		10 3±2 44	
E_2	Pil B84×BD 5	28	11 9±1 35		11 2±1 09		13 2±2 07		11.2±2 04		12.9±1 57		11 4±1 53	
	Mean III		11 9		10 5		15 3		13 2		13 8		11 6	

TABLE 3. 1937 HAND-POLLINATED SEEDLINGS, SERIES 8. MEAN GIRTHS AND GIRTH INCREMENTS OF BULKED FAMILIES OF MAIN AND SUBSIDIARY PARENTS, IN INCHES

(M.S.D.=min. 5% significant difference between means, assuming common s.e.'s. >=greater than, at 5% significance level or less)

Subsidiary parents	Measurement	Main parents			Mean	M.S.D.
		A Tjir 1	B AVROS 157	C Pil B84		
D PB 86	Girth 1946	19.0	21.0	18.0	19.33	Girth
	Girth 1955	28.4	34.8	28.3	30.50	
	Increment	9.4	13.8	10.3	11.17	
E PB 24	Girth 1946	22.3	21.3	20.7	21.43> G	
	Girth 1955	34.7	34.3	31.9	33.63> H	
	Increment	12.4	13.0	11.2	12.2	
						(DEFGH)
F PB 49	Girth 1946	26.3	26.0	24.1	25.47> DEGH	Girth 1946 2.60
	Girth 1955	41.7	44.1	38.3	41.37> DEGH	Girth 1955 3.23
	Increment	15.4	18.1	18.2	15.90> DEGH	Increment 2.06
G Gl 1	Girth 1946	17.5	19.8	17.7	18.33	
	Girth 1955	29.1	36.1	30.8	32.0	
	Increment	11.6	16.3	13.1	13.67> EH	
H BD 5	Girth 1946	16.3	21.7	19.3	19.10	
	Girth 1955	27.9	34.1	28.4	30.13	
	Increment	11.6	12.4	9.1	11.03	
						(ABC)
Mean	Girth 1946	20.28	21.96	19.96		Girth 1946 2.01
	Girth 1955	32.36	36.68> AC	31.54		Girth 1955 2.50
	Increment	12.08	14.72> AC	11.58		Increment 1.59

TABLE 4. HAND-POLLINATED SEEDLINGS, SERIES 8. INDIVIDUAL FAMILIES, GIRTH, IN INCHES

	Families	No. of trees	Mean girth, 50 in. from ground			
			1946	Families or parents with means inferior at 5% sig. or less	1955	Families or parents with means inferior at 5% sig. or less
A	Tjir 1×PB 86	61	19.0±0.72		28.4±1.19	
B	Tjir 1×PB 24	26	22.3±1.08	AA_2DE	34.7±1.76	AA_2DE_2
C	Tjir 1×PB 49	41	26.3±0.71	$AA_1A_2BB_1B_2$, $C_2DD_1D_2EE_1E_2$	41.7±1.31	$AA_1A_2BB_1B_2$, $DD_1D_2EE_1E_2$
D	Tjir 1×Gl 1	23	17.5±1.15		29.1±2.16	
E	Tjir 1×BD 5	5	16.3±2.12		27.9±3.34	
	Mean I	156	20.28		32.36	
A_1	AVROS 157×PB 86	51	21.0±0.75	AD_2E	34.8±1.72	AA_2DE_2
B_1	AVROS 157×PB 24	18	21.3±0.79	AA_2DE	34.3±1.59	AA_2E_2
C_1	AVROS 157×PB 49	46	26.0±0.69	$AA_1A_2BB_1B_2$, $C_2DD_1D_2EE_1E_2$	44.1±1.35	$AA_1A_2BB_1B_2$, $C_2DD_1D_2EE_1E_2$
D_1	AVROS 157×Gl 1	16	19.8±1.35		36.1±1.93	AA_2DEE_2
E_1	AVROS 157×BD 5	21	21.7±0.76	AA_2DE	34.1±1.76	AA_2E_2
	Mean II	152	21.96		36.68	I, III
A_2	Pil B84×PB 86	31	18.0±1.06		28.3±1.79	
B_2	Pil B84 ×PB 24	25	20.7±1.36		31.9±2.20	
C_2	Pil B84×PB 49	31	24.1±0.68	$AA_1A_2B_1B_2$, $DD_1D_2EE_1E_2$	38.3±1.31	$AA_2B_2DEE_2$
D_2	Pil B84 ×Gl 1	6	17.7±2.53		30.8±4.08	
E_2	Pil B84×BD 5	27	19.3±1.23		28.4±1.78	
	Mean III	120	19.96		31.54	
Minimum 5% sig. diff. between means, assuming common s.e.'s			2.01		2.50	

TABLE 5. 1937 HAND-POLLINATED SEEDLINGS, SERIES 8. ADDITIONAL FAMILIES. YIELD IN LB PER TREE PER ANNUM, GIRTH IN INCHES

	Families	No. of trees	Mean yield over 15 years of tapping		Mean girth 50 in. from ground	
			Method 1	Method 2	1946	1955
A.	AVROS 157×Pil B84	19	22.4±2.45	18.2±2.53	26.3±1.10>B	43.9±2.69
B.	Tjir 1×AVROS 157	14	19.9±1.94	18.7±2.25	21.6±1.12	38.4±2.65

TABLE 6. 1938 HAND-POLLINATED SEEDLINGS, SERIES 9. YIELD IN LB PER TREE PER ANNUM, GIRTH AND GIRTH INCREMENT IN INCHES

(> =greater than, at 5% significance level or less)

Groups by relationship of parents		Families	No. of trees	Mean yield per annum				Mean girth		Mean girth increment
				Over first 3 years of tapping		Over 15 years of tapping				
				Method 1	Method 2	Method 1	Method 2	1949	1957	1949–1957
I. None	A	RRIM 501 (Pil A44×Lun N) Tjir 1	23	16. ±1.32 >BDEGH	15.7±1.25 >BDEGH	21.2±2.57 >EGH	15.1±1.45 >EGH	27.9±0.82 >H	35.4±1.91 >H	7.5±1.47 >H
	B	RRIM 504 (Pil A44×Lun N)×Tjir 1	61	12.9±0.80 >DH	12.4±0.81 >DH	18.3±1.22 >EGH	16.3±1.11 >EGH	29.2±0.80 >EGH	40.1±1.53 >EFGH	10.9±0.91 >EFGH
		Mean I	84	13.9±0.69 >IV	13.3±0.68 >IV	19.2±1.14 >III IV	15.9±0.93 >III IV	28.8±0.62 >III IV	38.7±1.22 >III IV	9.9±0.78 >III IV
II. None	C	RRIM 500 (Pil A44×Pil B84)×Tjir 1	8	16.8±1.11 >BDEGH	14.3±1.31 >DGH	20.1±3.51 >H	13.1±2.55	30.8±2.76 >H	40.9±3.86 >EH	10.9±2.21 >EH
	D	RRIM 511 (Pil A44×Pil B16)×Tjir 1	11	10.0±1.20	9.2±1.18	15.6±2.37 >H	14.1±2.29 >H	27.8±1.75 >H	37.2±3.15 >H	9.4±1.63 >EH
		Mean II	19	12.8±0.88 >IV	11.3±0.84	17.7±2.05 >IV	13.6±1.71 >IV	28.9±1.28 >IV	39.0±2.45 >III IV	10.1±1.31 >III IV
III. Half sibs	E	RRIM 500 × RRIM 504 (Pil A44×Pil B84)×(Pil A44×Lun N)	71	12.5±0.65 >H	11.7±0.65	13.0±0.99 >H	10.3±0.78	26.1±0.68 >H	31.7±1.13 >H	5.6±0.57 >H
	F	RRIM 501 × RRIM 511 (Pil A44×Lun N) (Pil A44×Pil B16)	35	15.0±1.06 >DEGH	14.1±1.03 >DGH	17.2±1.61 EGH	13.7±1.29 >EH	27.9±1.02 >H	35.5±1.69 >H	7.6±0.85 >H
	G	RRIM 504 × RRIM 511 (Pil A44×Lun N) (Pil A44×Pil B16)	56	11.2±0.69	10.8±0.69	12.9±0.98 >H	11.6±0.89 >H	25.9±0.69 >H	34.2±1.25 >H	8.3±0.70 >H
		Mean III	162	12.6±0.44 >IV	11.9±0.43 >IV	13.9±0.65 >IV	11.5±0.54 >IV	26.4±0.44 >IV	33.4±0.75 >IV	7.0±0.40 >IV
IV. Sibs	H	RRIM 504 × RRIM 509 (Pil A44×Lun N) (Pil A44×Lun N)	38	9.9±0.86	9.5±0.89	9.8±0.86	8.7±0.90	22.7±0.84	26.1±1.16	3.4±0.49
		Mean IV	38	9.9±0.86	9.5±0.89	9.8±0.86	8.7±0.90	22.7±0.84	26.1±1.16	3.4±0.49

TABLE 7. 1938 HAND-POLLINATED SEEDLINGS, SERIES 9. PERCENTAGE AND EFFECT OF DRY TREES

(> =greater than, at 5% significance level or less)

Groups by relationship of parents	Families	Percentage of trees which became dry during 15 years of tapping			Loss of yield through dry trees	
		(a) For periods of less than 1 year	(b) For periods of 1 year or more	(a) + (b)	lb per tree per annum	%
I. None	A RRIM 501×Tjir 1	17.2± 6.98	41.4± 9.14	58.6± 9.15	6.1	28.8
	B RRIM 504×Tjir 1	18.3± 4.59	31.0± 5.49	49.3± 5.93	2.0	10.9
	Mean I	18.0± 3.84	34.0± 4.74	52.0± 4.99	3.3	17.2
II. None	C RRIM 500×Tjir 1	20.0±12.65	70.0±14.49	90.0± 9.49	7.0	34.8
	D RRIM 511×Tjir 1	25.0±12.50	50.0±12.91	75.0±12.50	1.5	9.6
	Mean II	22.7± 8.94	59.1±10.48>I	81.8± 8.22>I III IV	4.1	23.2
III. Half sibs	E RRIM 500×RRIM 504	23.1± 4.77>F	50.0± 5.66>F	73.1± 5.02>F G	2.7	20.8
	F RRIM 501×RRIM 511	7.5± 4.16	40.0± 7.75	47.5± 7.89	3.5	20.3
	G RRIM 504×RRIM 511	24.2± 5.28>F	24.2± 5.28	46.4± 6.15	1.3	10.1
	Mean III	20.1± 2.95	38.6± 3.59	58.7± 3.63	2.4	17.3
IV. Sibs	H RRIM 504×RRIM 509	14.6± 5.52	39.0± 7.62	53.7± 7.79	1.1	11.2
	Mean IV	14.6± 5.52	39.0± 7.60	53.7± 7.79	1.1	11.2

TABLE 8. 1938 HAND-POLLINATED SEEDLINGS, SERIES 9. YIELD IN LB PER TREE PER ANNUM, GIRTH IN INCHES

(> =greater than, at 5% significance level or less)

Families	No. of trees	Mean yield over 15 years of tapping		Mean girth 50 in. from ground	
		Method 1	Method 2	1949	1957
A RRIM 501×Pil B84	12	22.1±3.80>E	17.3±3.52	32.3±2.05>E	44.8±4.56>E
B Tjir 1×Pil B84	16	17.2±2.38	13.1±1.94	29.4±1.61	44.6±3.03>E
C Tjir 1×Tjir 16	25	21.3±1.79	17.8±1.90>E	30.8±1.36	41.4±2.08>E
D RRIM 507×Tjir 1	19	19.5±2.33>E	15.7±2.22	30.7±2.03	41.0±2.83>E
E RRIM 504×Pil B84	26	13.4±1.33	11.9±1.28	26.5±1.02	34.5±1.55

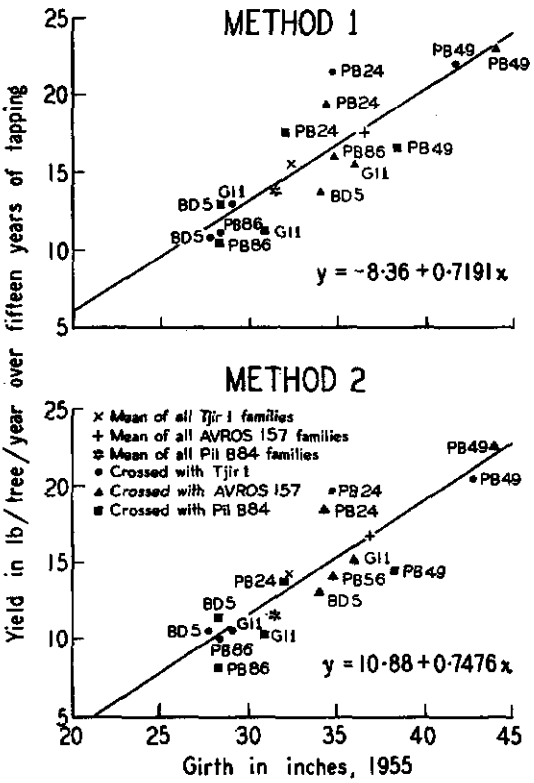

Figure 2. Regression of yield on girth (yield calculated by methods 1 and 2). 1937 hand-pollinated seedlings—Series 8.

seedlings and this reflected in the differences between the yields calculated by the two methods shown in *Figure 1*. Of the subsidiary parents, PB 24 and BD 5 produced seedlings which had a relatively high proportion of dry trees.

Relationship between Yield and Girth

When all fifteen families are considered, a highly significant linear regression of yield on girth is obtained. *Figure 2* shows the regression line when yields are calculated by methods 1 and 2.

Each of the main parents Tjir 1, AVROS 157 and Pil B84 produced seedlings which gave yields more or less as predicted by the regression lines, although the yield of the Pil B84 seedlings is rather lower than the yields are calculated by method 2.

The subsidiary parent PB 24 produced seedlings which yielded more than the regression line predicts, while the PB 86 and Gl 1 seedlings yielded rather less. The PB 49 and BD 5 seedlings conform fairly closely with the regression line.

Additional Families

In addition to the fifteen families already mentioned and compared, AVROS 157×Pil B84 and Tjir 1×AVROS 157 were tested. Their yields and girths are shown in *Table 5*. There is no significant difference between their yields but the difference between the yields calculated by the two methods is much greater in the case of AVROS 157×Pil B84 than in the case of Tjir 1×AVROS 157. The yields of both families compare favourably with those of the best of the fifteen other families, none of which yielded significantly more.

In 1946 the mean girth of AVROS 157×Pil B84 was significantly greater than that of Tjir 1×AVROS 157 but the difference in girth was not significant in 1955. The girths of both families compare favourably with those of the best of the fifteen other families, none of which had significantly greater girth in 1955.

Sharp (1951) stated that AVROS 157×Pil B84 was a high-yielding, exceptionally vigorous family with an average amount of brown bast. The later records confirm the vigour of the family but its value has been reduced by a high incidence of dry trees which is reflected in the difference of 4.2 lb per tree per year between the mean yield calculated by method 1 and that calculated by method 2.

Discussion

After an extra ten years of yield recording the value of AVROS 157 as a parent is much more obvious than it was to Sharp (1951) after five years of recording, and the inferiority of Pil B84 has also become more obvious, especially when the yields are calculated by method 2 to take dry trees into consideration.

The increased superiority of AVROS 157 as a parent is attributed mainly to the vigorous growth of its seedlings. It can be seen from

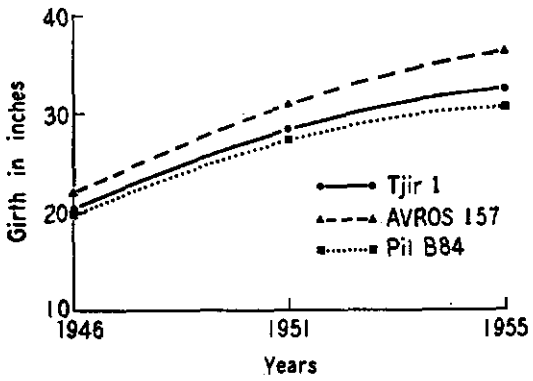

Figure 3. Mean girth of seedlings of Tjir 1, AVROS 157 and Pil B84 crossed with PB 86, PB 24, PB 49, Gl 1 and BD 5. 1937 hand-pollinated seedlings—Series 8.

Figure 1 that the yields of the AVROS 157 seedlings did not overtake those of the Tjir 1 seedlings until after the fourth year of tapping, and that their superiority increased thereafter. *Figure 3*, in which the growth from 1946 to 1955 of the seedlings of the main parents are compared, shows clearly the superior vigour of the AVROS 157 seedlings. PB 49 is confirmed as an excellent parent which produces high-yielding seedlings which are vigorous and relatively free from dry trees. PB 24, on the other hand, produces seedlings which, although high-yielding, are significantly less vigorous than the PB 49 seedlings and have a relatively high incidence of dry trees. PB 86, Gl 1 and BD 5 are clearly inferior as parents.

1938 HAND-POLLINATED SEEDLINGS, SERIES 9

In 1938 an inbreeding experiment was planned in which the following clones were to be crossed in all combinations:

Clone	*Parentage*
RRIM 501	Pil A44 × Lun N
RRIM 504	Pil A44 × Lun N
RRIM 509	Pil A44 × Lun N
RRIM 500	Pil A44 × Pil B84
RRIM 511	Pil A44 × Pil B16
Tjir 1	Unknown

Fourteen of the families were obtained. No fruits were obtained from the cross RRIM 501 × RRIM 504.

SHARP (1951) reported the girths in 1949 and yields of the progenies after three years of tapping, and found that the mean girth of the seedlings derived from outcrossing was significantly higher than that of the seedlings from crosses between half sibs, which in turn had a mean girth significantly higher than that of seedlings derived from crosses between sibs. Although the yields showed a similar trend, the differences were not significant.

The results after fifteen years of tapping are now available and are compared with the results after three years of tapping in *Table 6*. The girth and yield figures from six out of the fourteen families cited by Sharp have been omitted on the grounds that the number of seedlings in them was very low.

Although Sharp was unable to demonstrate significant differences in the mean yields of the groups of seedlings after three years of tapping, calculations of the mean yields after three years of tapping, when the six families with small numbers of seedlings are omitted, show that the mean yield of the seedlings derived from crosses between sibs is significantly lower than that of the other groups.

After fifteen years of tapping, the mean yield of the seedlings derived from outcrosses is significantly greater than that of the seedlings derived from half-sib crosses which in turn is significantly greater than that of the seedlings derived from crosses between sibs.

Girth

The mean girths and girth increments are given in *Table 6*.

The mean girth increment from 1949 to 1957 of the seedlings derived from outcrossing is significantly greater than that of the seedlings derived from half-sib crosses which in turn is significantly greater than that of the seedlings from sib crosses. Thus the mean girths in 1957 demonstrate even more clearly than the mean girths in 1949 the differences in vigour between the groups of seedlings.

Incidence of Dry Trees

While there are significant differences between individual families and between the groups of seedlings in the percentage of trees

which became dry during fifteen years of tapping, there is no clear evidence of a trend in the incidence of dry trees according to the degree of inbreeding of the seedlings.

The extent to which the incidence of dry trees has affected the yields of the different families is shown in *Table 7*. The drop in lb per tree per year caused by dry trees ranges from 7.0 for the family RRIM 500×Tjir 1 to 1.1 in the family RRIM 504×RRIM 509. Assuming a stand of 120 trees per acre these figures would represent a loss of 840 and 132 lb per acre per year respectively over 15 years of commercial tapping. As already indicated above, the mere quotation of the percentage of dry trees in the evaluation of seedling families is very misleading, a point which is well illustrated in *Table 7*. Seventy-five per cent of the trees of the family RRIM 511×Tjir 1 were dry at one time or another during the fifteen years of tapping and the loss of yield was 1.5 lb per tree per year. The corresponding figures for the family RRIM 501×Tjir 1 are 58.6% and 6.1 lb per tree per year. Even when the dry trees are separated into those that were never dry for a whole year and those which were dry for a year or more, the percentage figures are misleading.

Additional Families

In addition to the families compared in the inbreeding experiment, RRIM 501×Pil B84, Tjir 1×Pil B84, Tjir 1×Tjir 16, RRIM 507×Tjir 1 and RRIM 504×Pil B84 were tested. Their yields and girths are shown in *Table 8*.

The family RRIM 504×Pil B84, an outcross, is not significantly different in yield or girth from the three half-sib families in the inbreeding experiment, two of which have RRIM 504 as a parent. It is however significantly lower in yield and girth than RRIM 504×Tjir 1 one of the outcrosses in the inbreeding experiment.

RRIM 501 combines better with Pil B84 than do Tjir 1 or RRIM 504.

Discussion

The differences in girth and yield between the outcrosses, the half-sib crosses and the sib crosses are more pronounced after fifteen years of tapping when Sharp (1951) concluded that the depressing effect in vigour of inbreeding had been clearly demonstrated. Sharp further stated that it might be inferred from the results that, as a general rule, in any field set aside for the production of seed for commercial planting, it would be unwise to include two closely related clones unless the value of the crosses of these two clones is known to be high.

Sharp's conclusion about inbreeding depression is debatable. The choice of parents in the experiment allows the interpretation that seedlings of which Tjir 1 is a parent are more vigorous and eventually higher yielding than seedlings bred from combinations of the RRIM series clones used.

If the girths and yields of the individual families are considered, it will be seen that the half-sib cross RRIM 501×RRIM 511 produced seedlings which were inferior in yield and vigour to only one of the four outcrossed families. RRIM 501 has subsequently proved to be a good parent. The family RRIM 501×RRIM 511 is the smallest of the three half-sib families in Group 3 and, since the group means are weighed, has relatively little effect on the mean. On the other hand, the progenies of other three half-sib and sib crosses have RRIM 504 as a parent. RRIM 504 outcrossed with Pil B84 produced seedlings which were not significantly different in yield or girth from the progenies of the half-sib crosses, but were inferior in both respects to those of the family RRIM 504×Tjir 1. Tjir 1 has already been shown (Series 8) to be a good parent.

Various degrees of inbreeding have been practised since 1938 and the data obtained do not support the hypothesis that inbreeding of *Hevea brasiliensis* commonly results in a depression of vigour, at least in the early stages of inbreeding. The results of the more recent inbreeding will be discussed in a future publication.

1939 HAND-POLLINATED SEEDLINGS, SERIES 10

The yields and girths of the three families with more than ten seedlings produced in 1939 are shown in *Table 9*.

There are no significant differences between

Lun N×RRIM 501 (a backcross) and Lun N×RRIM 500. The family Tjir 1×Pil B84 is significantly superior to Lun N×RRIM 501 in yield calculated by method 1, and in girth, but not in yield calculated by method 2.

Unfortunately the Series 10 seedlings suffered from serious neglect during the war years (SHARP, 1951) and it is therefore dangerous to draw firm conclusions from the results.

1940 HAND-POLLINATED SEEDLINGS, SERIES 11

The yields and girths of the six families with more than ten seedlings produced in 1940 are shown in *Table 10*.

The highest-yielding and most vigorous families are Tjir 1×RRIM 528 and Pil B84×RRIM 501. BR 2×Tjir 1 is the lowest yielding.

1941 HAND-POLLINATED SEEDLINGS, SERIES 12

The yields and girths of the ten families with ten or more seedlings produced in 1941 are shown in *Table 11*.

The outstanding family is Tjir 1×RRIM 509 which yielded significantly more than seven of the other families when yields were calculated by method 1 and significantly more than four families when yields were calculated by method 2. Tjir 1×RRIM 523 yielded significantly more than RRIM 505×Lun N.

Although there were significant differences in girth between the families in 1947, four years after planting out as two year old stumps, there were no significant differences in 1955, twelve years after planting.

It should be remembered when considering the yields and girths of the 1941 hand-pollinated seedlings that they were planted in the field without replication.

CONCLUSION

The additional data on girth and yield which have become available since SHARP (1951) reported on the hand pollinated seedlings produced during Phase II (1937–1941) of the breeding programme confirm his conclusions that the best parents for inclusion in seed gardens used were Tjir 1, AVROS 157, PB 49, RRIM 501 and RRIM 509 and that PB 86, BD 5 and Gl 1 were among the least desirable. AVROS 157 now appears to be a better parent than Tjir 1 by virtue of the greater vigour and subsequent higher yield of its progeny. PB 24 is confirmed as a producer of high yielding seedlings, but too high a proportion of them became dry to warrant its use as a parent in seed gardens.

Sharp's conclusions regarding inbreeding depression, based on the vigour and yield of the seedlings produced in 1938 are not substantiated by subsequent experience; the most likely explanation of his findings is that Tjir 1 was a parent of all the outcrosses and might therefore be responsible for their superiority over the inbred families. It is unfortunate that there are insufficient seedlings of the cross RRIM 501 ×RRIM 509 to be considered. However this cross was made again in an inbreeding experiment in 1960 and there is no indication of inbreeding depression in the seedling family. RRIM 501 selfed seedlings have been produced frequently by hand pollinations since 1959 and show no signs of lack of vigour compared with outcrosses.

It is clear that hand-pollinated seedlings should not be tapped alternate daily on a half spiral cut (S/2.d/2.100%) because the resulting incidence of dryness makes comparisons of the families difficult. A family with a relatively high incidence of dry trees on S/2.d/2.100% might not have a high incidence when tapped third daily on a half spiral cut (S/2.d/3.67%) which is the standard tapping system for seedlings in commercial practice.

From the evidence presented it seems probable that careful interpretation of the yields, girths and incidence of dry trees over the first five years of tapping of trials of hand-pollinated seedlings is sufficient to make possible the recognition of the best seedling families and the best parents.

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TABLE 9. 1939 HAND-POLLINATED SEEDLINGS, SERIES 10. YIELD IN LB PER TREE PER ANNUM AND GIRTH IN INCHES
(> = greater than, at 5% significance level or less)

Families	No. of trees	Mean yield over 15 years of tapping		Mean girth 50 in. from ground	
		Method 1	Method 2	1947	1955
A Lun N×RRIM 501	26	11.6±1.09	10.5±0.98	16.9±0.90	27.7±1.14
B Lun N×RRIM 500	21	14.3±1.91	13.1±1.92	19.7±1.30	31.5±2.07
C Tjir 1×Pil B 84	126	14.6±0.66>A	12.3±0.65	20.2±0.37>A	35.0±0.74>A

TABLE 10. 1940 HAND-POLLINATED SEEDLINGS, SERIES 11. YIELD IN LB PER TREE PER ANNUM AND GIRTH IN INCHES
(> = greater than, at 5% significance level or less)

Families	No. of trees	Mean yield over 15 years of tapping		Mean girth at 50 in. from ground	
		Method 1	Method 2	1949	1955
A BR 2×Tjir 1	219	13.7±0.48	12.5±0.42	18.6±0.26	27.5±0.44
B Tjir 1×RRIM 527	36	16.4±1.53	14.3±1.39	17.1±0.77	27.4±1.20
C Tjir 1×RRIM 529	14	16.5±3.23	12.7±1.73	18.8±1.51	28.6±2.20
D Tjir 1×RRIM 526	19	17.7±3.00	14.8±2.06	18.5±0.98	28.2±1.97
E Tjir 1×RRIM 528	31	20.3±1.91>A	17.9±1.62>AC	20.5±0..82>AB	33.0±1.45>AB
F Pil B84×RRIM 501	10	20.1±3.50	19.5±3.35>A	19.7±128	29.2±2.64

TABLE 11. 1941 HAND-POLLINATED SEEDLINGS, SERIES 12. YIELD IN LB PER TREE PER ANNUM AND GIRTH IN INCHES
(> = greater than, at the 5% significance level or less)

Families	No. of trees	Mean yield over 11 years of tapping		Mean girth at 50 in. from ground	
		Method 1	Method 2	1947	1955
A Tjir 1×RRIM 500	15	16.0±3.70	14.5±3.08	12.7±1.23	22.5±2.01
B Tjir 1×RRIM 506	28	14.6±1.45	12.2±1.13	13.3±1.02	25.7±1.57
C Tjir 1×RRIM 509	32	20.9±1.69>BEFGHIJ	18.5±1.68>BEFG	15.2±0.94>D	26.1±1.15
D Tjir 1×RRIM 523	10	17.8±2.00>E	16.2±2.24>E	11.1±1.33	26.3±2.01
E RRIM 505×Lun N	26	10.8±1.34	10.3±1.32	12.8±0.85	25.1±1.10
F RRIM 505×RRIM 514	36	15.4±1.08	14.3±1.11	15.7±0.62>ABDE	26.8±0.79
G RRIM 514×RRIM 500	16	13.0±2.23	10.9±2.07	16.3±1.47>DE	24.6±2.09
H RRIM 514×RRIM 501	30	15.6±1.91	14.7±1.89	14.3±0.68>D	24.1±1.15
I RRIM 514×RRIM 506	25	15.5±1.69	14.4±1.55	15.1±0.99>D	24.6±1.09
J RRIM 514×Lun N	43	15.3±1.20	14.4±1.18	16.2±0.67>ABDE	26.7±1.04

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