J. Rubb. Res. Inst. Malaya, **23(1)**, 23–31 (1970)

Yield-Girth Relationship Studies on Hevea

R. NARAYANAN and HO CHAI YEE

The pattern of relationship between yield and girth of trees of Hevea brasiliensis *has been examined for ten clones and for three years. Linear and curvilinear forms of expression were considered. A simple linear expression of yield on girth within clones was found to be most suitable; the constants of the equations varied between years and between clones. The regression on girth accounted for 16 – 72% of the variance of individual tree yields. Estimated yields for 18-inch girth varied between 70 and 95% of yields estimated for 20-inch girth.*

Girth has been used extensively as a parameter in growth and yield estimation of tree crops, its relationship to yield providing a means of assessing the growth factor in clonal performance and thereby eliminating growth differences in clonal comparisons. In clones of *Hevea*, girth and the number of latex vessel rings within the cortical tissue have together accounted for almost all the tree-to-tree variation in yield for a few clones (RUBBER RESEARCH INSTITUTE OF MALAYA, 1966). Tree dry weight was found by PEARCE (1952), CONSTABLE (1955), DANCER (1964) and SHORROCKS, *et al.* (1965) to be closely proportional to an elevated power of girth:

$$y = ax^b \quad \ldots \quad \ldots \quad (1)$$

where x is the girth, y is the tree dry weight and a and b are constants, b normally being in the range 2–4. They calculated a and b by transforming the x and y data to logarithms and fitting the linear regression:

$$\log y = \log a + b \log x$$

to the transformed data.

BOLTON (1960) and PAARDEKOOPER (1953, 1964) used the same form of expression to relate girth and latex yield in rubber of individual *Hevea* trees, reporting respectively b values of 1.2 and 2–4 as giving the best fit for the data. The present investigation aimed at determining whether a curvilinear expression such as Equation 1 would fit *Hevea* yield data better than the linear expression of the type:

$$y' = c + dx \quad \ldots \quad \ldots \quad (2)$$

in which c and d are constants.

EXPERIMENTAL

Individual tree yield and girth records for forty to sixty trees per clone for ten selected clones have been taken from a simple lattice experiment of hundred clones. In the two plots of each clone, alternate trees were utilised for the present study. The individual tree yield and girth recordings used were for the three-year period: January–December 1962 (first year), January–December 1963 (second year) and January–December 1964 (third year). Yield was recorded monthly in grams per tapping for each year. Girths were measured in cm at a certain height (60 inches) at the end of each year, *i.e.*, in December 1962, 1963 and 1964.

For each clone, individual tree yield records were plotted by year against corresponding girths. The linear and curvilinear relationships giving the best fit were calculated by applying the method of least squares to the data directly or after logarithmic transformation.

To compare the goodness of fit of the two equations to the observed data, departures of the observed and expected yields were calculated at each of the observed girth values, using both relationships for all thirty combinations of clones and years. From the individual departures (positive or negative), the average departure was calculated by taking the sum of squares of the individual departures for each clone in each recording year, dividing by the number of trees less two (since two constants have been estimated in each of the equations) and determining the square-root. The mean yields of individual trees vary from year to

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year and from clone to clone, hence the average departures were standardised for comparison by expressing them as percentages of the respective mean yields:

Percentage departure (% C.V.) = (Average departure/mean yield)×100

Standard errors as well as the 95% lower and upper confidence limits were calculated. For the linear equation, the estimate of yield (Y') at any given girth x_o is

$$Y' = c + dx_o$$

$$\text{S.E. of } Y' = Sy\sqrt{\frac{1}{n} + \frac{(x_o - \bar{x})^2}{\Sigma(x-\bar{x})^2}} \quad \ldots \quad (3)$$

where Sy is the residual standard deviation and $\bar{x}$ is the mean for girths.

This is the standard error of the estimated Y' for trees of given girth x_o.

TABLE 1. MEANS, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIATION FOR YIELD AND GIRTH OF TREES FOR DIFFERENT CLONES

Clone	Year	No. of trees	Girth (cm)			Yield (g)		
			Mean	S.D.	C.V.%	Mean	S.D.	C.V.%
RRIM 501	1	59	55.1	2.9	5.18	26.2	6.1	23.4
	2	59	58.5	3.5	5.98	37.1	10.4	28.0
	3	59	60.6	3.9	6.45	42.1	12.7	30.1
RRIM 603	1	44	57.5	3.5	6.10	19.1	5.0	26.4
	2	44	62.0	4.8	7.76	22.3	7.0	31.5
	3	44	65.3	5.6	8.54	22.2	7.9	35.5
RRIM 607	1	59	57.0	3.6	6.24	22.6	7.4	32.9
	2	59	61.2	4.7	7.71	24.9	10.0	40.1
	3	58	64.6	5.9	9.07	33.6	13.6	40.4
RRIM 614	1	55	56.4	2.5	4.48	29.8	6.0	20.1
	2	55	60.2	3.2	5.33	39.1	11.1	28.4
	3	55	64.0	4.4	6.92	53.9	18.3	33.9
RRIM 623	1	58	61.6	4.7	7.70	23.5	6.5	27.7
	2	58	66.3	5.5	8.37	28.7	9.1	31.8
	3	58	70.4	6.2	8.78	34.7	12.4	35.8
RRIM 632	1	63	61.2	4.3	7.10	20.3	5.5	26.8
	2	63	66.2	5.1	7.68	23.6	7.0	29.6
	3	63	70.3	6.1	8.74	24.5	10.0	40.7
RRIM 701	1	66	59.7	4.5	7.53	22.5	5.2	22.9
	2	66	62.7	4.8	7.64	34.0	10.9	32.1
	3	66	65.8	5.5	8.33	38.1	14.6	38.2
RRIM 707	1	57	60.4	4.9	8.15	26.3	8.0	30.6
	2	57	64.9	5.4	8.36	32.4	10.0	30.8
	3	57	69.0	6.7	9.64	48.3	12.8	26.5
PB 5/51	1	60	56.1	2.7	4.90	21.6	3.8	17.7
	2	60	59.9	3.4	5.69	25.9	5.2	20.0
	3	60	63.1	4.2	6.67	31.1	6.5	20.9
Ch 30	1	58	57.4	2.9	5.00	11.1	3.3	29.7
	2	58	62.3	3.8	6.09	18.0	6.9	38.4
	3	58	66.5	4.3	6.52	20.6	9.4	45.4

TABLE 2. LINEAR AND CURVILINEAR RELATIONSHIPS BETWEEN YIELD (Y) AND GIRTH (X) FOR DIFFERENT CLONES

Clone	Year	n = No. of trees	Linear relationship			Curvilinear relationship		
			$y^1 = c + dx$	Correlation coefficient (r)	Residual variance	$\log y = \log a + b \log x$	Correlation coefficient (r)	Residual variance
RRIM 501	1	59	$1.469x - 54.79$	0.687 ***	20.06	$3.127 \log x - 4.038$	0.670 ***	0.0060
	2	59	$2.198x - 91.41$	0.739 ***	49.96	$3.517 \log x - 4.660$	0.711 ***	0.0081
	3	59	$2.331x - 99.29$	0.719 ***	78.99	$3.404 \log x - 4.461$	0.726 ***	0.0081
RRIM 603	1	44	$0.957x - 35.99$	0.667 ***	14.41	$2.859 \log x - 3.763$	0.657 ***	0.0076
	2	44	$1.201x - 52.20$	0.826 ***	15.97	$3.578 \log x - 5.082$	0.833 ***	0.0065
	3	44	$0.984x - 42.08$	0.697 ***	32.66	$3.358 \log x - 4.774$	0.718 ***	0.0149
RRIM 607	1	59	$1.148x - 42.86$	0.550 ***	39.18	$2.938 \log x - 3.825$	0.554 ***	0.0139
	2	59	$1.340x - 57.09$	0.634 ***	60.60	$3.806 \log x - 5.435$	0.679 ***	0.0187
	3	58	$1.628x - 71.49$	0.703 ***	94.85	$3.892 \log x - 5.553$	0.727 ***	0.0209
RRIM 614	1	55	$1.406x - 49.53$	0.593 ***	23.74	$2.644 \log x - 3.163$	0.598 ***	0.0047
	2	55	$2.466x - 109.41$	0.711 ***	62.22	$4.187 \log x - 5.877$	0.692 ***	0.0101
	3	55	$3.067x - 142.23$	0.742 ***	153.33	$4.671 \log x - 6.735$	0.674 ***	0.0234
RRIM 623	1	58	$0.826x - 27.38$	0.602 ***	27.42	$2.124 \log x - 2.443$	0.614 ***	0.0085
	2	58	$0.977x - 36.12$	0.596 ***	54.46	$2.465 \log x - 3.052$	0.602 ***	0.0144
	3	58	$1.584x - 76.75$	0.788 ***	59.43	$3.281 \log x - 4.542$	0.794 ***	0.0094
RRIM 632	1	63	$0.845x - 31.40$	0.674 ***	16.46	$2.584 \log x - 3.322$	0.663 ***	0.0082
	2	63	$1.156x - 52.91$	0.842 ***	14.44	$3.519 \log x - 5.052$	0.826 ***	0.0066
	3	63	$1.371x - 71.92$	0.846 ***	28.72	$4.197 \log x - 6.392$	0.853 ***	0.0098
RRIM 701	1	66	$0.792x - 24.84$	0.693 ***	14.00	$2.091 \log x - 2.372$	0.663 ***	0.0060
	2	66	$1.410x - 54.39$	0.620 ***	74.33	$2.315 \log x - 2.646$	0.555 ***	0.0133
	3	66	$1.612x - 67.98$	0.607 ***	135.74	$2.856 \log x - 3.641$	0.575 ***	0.0216
RRIM 707	1	57	$1.363x - 56.06$	0.835 ***	19.85	$3.266 \log x - 4.414$	0.835 ***	0.0060
	2	57	$0.796x - 19.25$	0.433 ***	82.54	$1.755 \log x - 1.688$	0.452 ***	0.0162
	3	57	$0.980x - 19.37$	0.509 ***	124.02	$1.511 \log x - 1.107$	0.513 ***	0.0115
PB 5/51	1	60	$0.582x - 11.06$	0.418 ***	12.28	$1.586 \log x - 1.447$	0.402 **	0.0057
	2	60	$0.941x - 30.45$	0.619 ***	16.88	$2.207 \log x - 2.517$	0.594 ***	0.0053
	3	60	$0.675x - 11.47$	0.436 ***	34.84	$1.455 \log x - 1.134$	0.436 ***	0.0073
Ch 30	1	58	$0.166x + 1.55$	0.144 N.S.	10.83	$0.876 \log x - 0.514$	0.142 N.S.	0.0173
	2	58	$1.111x - 51.21$	0.610 ***	30.46	$3.867 \log x - 5.713$	0.593 ***	0.0193
	3	58	$1.409x - 73.10$	0.652 ***	51.28	$4.946 \log x - 7.745$	0.666 ***	0.0248

***P < 0.001 **P < 0.01 N.S. : Not significant

The 95% lower and upper confidence limits for the estimated yields using the linear functions are given by $Y' \pm t \times$(S.E.). Using $t=2$, this has been tabulated for the three years and for the ten clones using Equation 3.

In the case of the curvilinear expression, the estimated yields, their standard errors (using Equation 3) and the 95% lower and upper confidence limits have been initially worked out on logarithmic basis. The estimated yields and the 95% lower and upper confidence limits were then transformed to original units (by taking anti-logarithms).

RESULTS

Table 1 shows the means, standard deviations

(S.D.) and coefficients of variations (C.V. = 100 × S.D./mean) of the yield and girth records of the individual trees for each of the three years for all the ten clones. *Table 2* gives details of the fitted equations and in *Table 3* are shown the average and percentage departures of the observed and expected yields. *Table 4* gives estimates of yields and their 95% confidence limits for trees of small and large girths for the various clones and years. *Figures 1* to *3* illustrate for three representative situations the fits obtained to the derived equations and their 95% confidence limits to individual tree yield records.

TABLE 3. AVERAGE AND PERCENTAGE DEPARTURES IN YIELDS USING THE LINEAR AND CURVILINEAR RELATIONSHIPS FOR DIFFERENT CLONES

Clone	Year	Average departure		% Departure	
		Linear	Curvilinear	Linear	Curvilinear
RRIM 501	1	4.48	4.51	17.1	17.2
	2	7.07	7.14	19.1	19.2
	3	8.89	8.99	21.1	21.4
RRIM 603	1	3.80	3.79	19.9	19.9
	2	4.00	4.15	18.0	18.6
	3	5.72	5.93	25.7	26.7
RRIM 607	1	6.26	6.38	27.7	28.3
	2	7.79	8.20	31.3	33.0
	3	9.74	10.80	29.0	32.1
RRIM 614	1	4.87	4.89	16.3	16.4
	2	7.89	8.22	20.2	21.0
	3	12.38	14.02	23.0	26.0
RRIM 623	1	5.24	5.25	22.3	22.3
	2	7.38	7.51	25.8	26.2
	3	7.71	7.52	22.2	21.7
RRIM 632	1	4.06	4.07	20.0	20.0
	2	3.80	3.89	16.1	16.5
	3	5.36	5.34	21.8	21.8
RRIM 701	1	3.74	3.75	16.7	16.7
	2	8.62	8.65	25.4	25.4
	3	11.65	11.79	30.6	30.9
RRIM 707	1	4.46	4.54	17.0	17.3
	2	9.09	9.20	28.0	28.4
	3	11.14	11.27	23.1	23.3
PB 5/51	1	3.50	3.52	16.2	16.3
	2	4.11	4.14	15.9	16.0
	3	5.90	5.93	19.0	19.1
Ch 30	1	3.29	3.33	29.7	30.0
	2	5.52	5.49	30.7	30.6
	3	7.16	7.25	34.7	35.2

The results show that the mean yield generally increases from year to year for any one clone and also the yield varies from clone to clone for any one year. The C.V. of the individual tree yield records varies in the range of about 20–45% for the different clones, the clone PB 5/51 showing the lowest variation in all the three years. The C.V. of the individual tree girth data varies between 4.5 and 9.6%, the C.V. of both yield and girth shows a tendency to increase from the first to the third year of tapping.

DISCUSSION

In almost all cases (Ch 30 during first year excepted), similar significant correlations were obtained by using the two equations, the correlation coefficients varying 0.40 – 0.85. In other words, 16 – 72% of the variations in individual

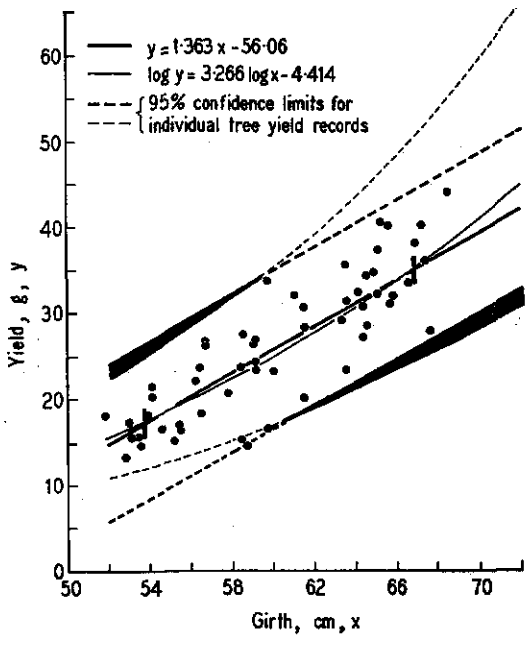

Figure 1. Yield-girth relationship of individual trees of clone RRIM 707, first year.

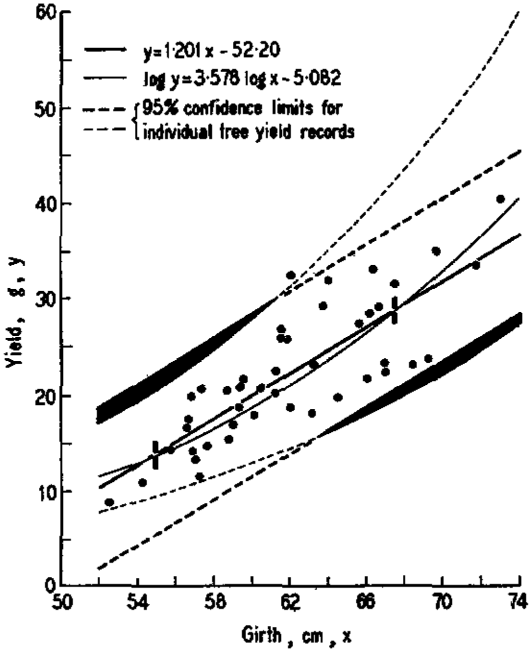

Figure 2. Yield-girth relationship of individual trees of clone RRIM 603, second year.

tree yield records have been accounted for by the linear or curvilinear relationships. In both cases, the two constants of the equations are always almost significantly different from zero —indicating the need of a two-parameter equation.

In most cases, the linear relationship gives slightly lower or similar percentage departures as the curvilinear (*see Table 3*), showing relationship between yield and girth of individual trees to be as effectively represented by the linear as by the curvilinear relationship in the observed range of girths for the clones and years examined. *Figures 1* to *3* demonstrate the similarity over the medial range of the data (see the range between the interactions marked in the *Figures*) of the yield estimates based on girth by the two types (linear y' and curvilinear y) of relationships. The linear equation in this range exceeds the curvilinear by

$$(y' - y) = c + dx - ax^b$$

which attains a maximum where

$$\frac{d(y' - y)}{dx} = d - abx^{b-1} = 0$$

or

$$x = \frac{(d)^{1/b-1}}{(ab)}$$

Table 5 gives the girthing at which these differences attain their maxima and the calculated values of these maxima in grams per tree and as percentage of the average estimation by the two relationships. The percentage differences vary from 2–10 for the different years and clones. Also, the 95% lower confidence limit for the linear estimates at the maximum point encompasses in most of the cases the estimates obtained by the curvilinear relationships. Outside the medial range, the curvilinear estimate exceeds the linear estimate by increasingly large amounts in both directions *(Figures 1* to *3).*

The hatchings on *Figures 1* to *3* show that, for the two relationships, the upper confidence limits for the lower girth ranges and the lower confidence limits for the upper girth ranges are concordant and fit the data equally satis-

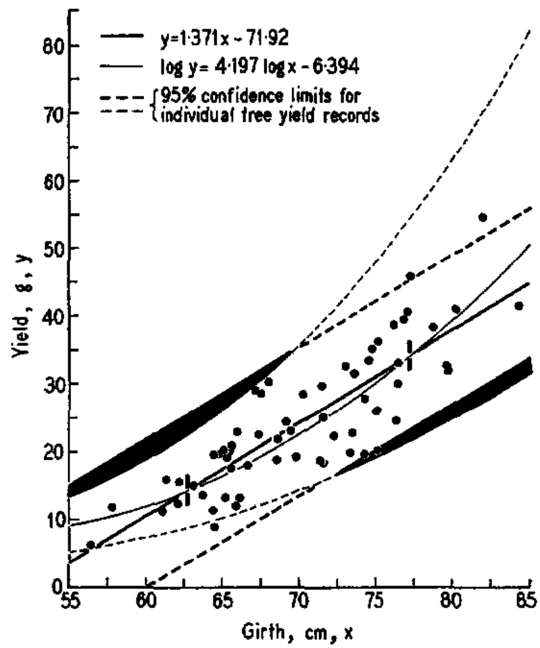

Figure 3. Yield-girth relationship of individual trees of clone RRIM 632, third year.

TABLE 4. ESTIMATED YIELDS (G) AND THEIR 95% LOWER AND UPPER CONFIDENCE LIMITS USING LINEAR AND CURVILINEAR RELATIONS FOR DIFFERENT CLONES

Clone	First year (January – December 1962)											
	$x = 50$ cm						$x = 70$ cm					
	Linear			Curvilinear			Linear			Curvilinear		
	L	E	U	L	E	U	L	E	U	L	E	U
RRIM 501	16.3	18.7	21.1	17.5	19.4	21.4	41.8	48.1	54.3	44.3	55.5	69.6
RRIM 603	9.1	11.9	14.6	10.7	12.4	14.5	26.7	31.0	35.3	26.3	32.5	40.1
RRIM 607	10.9	14.5	18.2	12.4	14.7	17.4	31.3	37.5	43.7	30.6	39.5	50.8
RRIM 614	17.2	20.8	24.4	18.8	21.3	24.1	41.7	48.9	56.1	41.8	51.9	64.3
RRIM 623	10.3	13.9	17.6	12.5	14.7	17.2	27.6	30.5	33.3	26.8	30.0	33.5
RRIM 632	8.0	10.9	13.7	10.0	11.7	13.7	25.4	27.8	30.1	24.9	27.9	31.3
RRIM 701	12.6	14.8	17.0	13.6	15.2	17.0	28.3	30.6	32.9	27.6	30.7	34.0
RRIM 707	9.3	12.1	14.8	12.1	13.6	15.3	36.7	39.3	41.9	37.0	40.9	45.2
PB 5/51	15.8	18.0	20.3	15.8	17.7	19.9	25.0	29.7	34.4	24.4	30.2	37.5
Ch 30	–	–	–	–	–	–	–	–	–	–	–	–

Clone	Second year (January – December 1963)											
	$x = 55$ cm						$x = 75$ cm					
	Linear			Curvilinear			Linear			Curvilinear		
	L	E	U	L	E	U	L	E	U	L	E	U
RRIM 501	26.9	29.5	32.1	26.8	28.9	31.2	64.5	73.4	82.4	67.9	86.1	109.1
RRIM 603	11.7	13.9	16.0	12.6	13.9	15.4	34.4	37.9	41.4	36.3	42.3	49.2
RRIM 607	13.2	16.6	19.9	13.4	15.4	17.7	27.1	43.3	49.7	39.5	50.2	63.7
RRIM 614	22.1	26.2	30.3	22.7	25.7	29.1	65.4	75.6	85.7	71.7	94.3	123.8
RRIM 623	13.2	17.6	22.0	14.5	17.3	20.6	34.3	37.2	40.0	32.5	37.1	42.4
RRIM 632	8.3	10.6	13.0	10.5	11.8	13.4	31.8	33.8	35.7	32.1	35.2	38.6
RRIM 701	19.1	23.1	27.2	21.2	24.1	27.4	45.4	51.3	57.2	41.7	49.4	58.6
RRIM 707	19.5	24.5	29.6	19.6	23.2	27.5	35.3	40.5	45.6	34.1	40.0	46.9
PB 5/51	19.4	21.3	23.2	19.5	21.1	22.8	35.3	40.1	45.0	34.8	41.9	50.3
Ch 30	6.7	9.9	13.0	8.6	10.4	12.6	27.0	32.1	37.2	26.2	34.5	45.5

TABLE 4 (Continued)

Clone	Third year (January – December 1964)											
	x = 60 cm						x = 80 cm					
	Linear			Curvilinear			Linear			Curvilinear		
	L	E	U	L	E	U	L	E	U	L	E	U
RRIM 501	38.2	40.6	42.9	37.2	39.1	41.3	75.4	87.2	99.0	81.7	104.3	133.2
RRIM 603	14.6	17.0	19.4	14.0	15.7	17.7	31.7	36.6	41.5	33.1	41.3	51.7
RRIM 607	22.9	26.2	29.4	20.9	23.3	26.1	51.5	58.7	66.0	56.7	71.5	90.2
RRIM 614	37.3	41.8	46.3	32.8	37.3	42.3	90.5	103.1	115.8	102.4	142.8	198.9
RRIM 623	14.3	18.3	22.3	17.4	19.6	22.1	46.2	50.0	53.8	45.3	50.3	56.0
RRIM 632	7.7	10.4	13.0	10.5	11.7	13.2	35.3	37.8	40.3	35.4	39.3	43.6
RRIM 701	24.5	28.7	32.9	24.2	27.3	30.9	53.0	61.0	69.0	50.0	62.2	77.3
RRIM 707	34.5	39.5	44.5	33.9	37.9	42.4	53.3	59.1	64.8	51.8	58.5	66.2
PB 5/51	27.1	29.0	30.9	26.7	28.4	30.2	36.1	42.5	48.9	35.4	43.1	52.5
Ch 30	8.0	11.4	14.9	9.4	11.3	13.4	33.4	39.6	45.8	34.8	46.7	62.6

L = Lower limit U = Upper limit E = Estimate x = Girth

factorily. As girth increases over the higher range, however, the upper confidence limit of the curvilinear relationship increases very rapidly and diverges increasingly from that of the linear relationship and from the scatter of the actual observations. The upper confidence limit of the linear relationship encompasses the data much more closely, indicating greater concordance of yield with girth in the larger trees. Conversely, as girth decreases over the lower range, the lower confidence limit of the linear relationship departs increasingly from the scatter of observations and the lower confidence limit of the curvilinear relationship encompasses the data more closely, indicating decreasing adequacy of a simple linear representation of the yield/girth relationship and the importance of overall growth in determining yield where the trees are small. The similarity in magnitude of the b values recorded in *Table 3* with those recorded for dry weight/girth relationships suggests indeed that growth influences are involved. In this connection, it is of practical interest to examine the yields obtained from a smaller girth through earlier opening than that normally recommended. Using the curvilinear expression for the first year of tapping, the estimated yields for trees opened at 18-inch (45.7 cm) and 20-inch (50.8 cm) girth have been given in *Table 6*. The estimated yields at 18-inch girth have been expressed as a percentage of those estimated at 20 inches. These percentages vary 80–85% for clones RRIM 623, RRIM 701 and PB 5/51, and between 70 and 76% for others.

In the absence of a clear superiority of the curvilinear relationship over the linear one in the entire observed range of the girth data examined, the linear relationship of yield/girth has been preferred because of its simplicity.

Clonal and Year-to-Year Differences in Yields

After studying the pattern of relationship between yield and girth of individual trees, clonal differences in each of the three years and also year-to-year differences for each of the

TABLE 5. GIRTH AND CORRESPONDING MAXIMUM AND PERCENT MAXIMUM DIFFERENCE ATTAINED BETWEEN LINEAR AND CURVILINEAR YIELD ESTIMATES

Clone	Year	Girth (cm)	Maximum diff. (g)	% Max. diff.†
RRIM 501	1	55.5	0.61	2.31
	2	58.9	1.24	3.31
	3	61.2	1.53	3.58
RRIM 603	1	58.7	0.55	2.76
	2	61.4	0.89	4.22
	3	62.9	1.38	7.22
RRIM 607	1	57.9	1.03	4.45
	2	59.6	1.85	8.45
	3	61.6	2.92	10.73
RRIM 614	1	57.2	0.50	1.63
	2	59.1	1.59	4.46
	3	60.9	4.61	10.91
RRIM 623	1	64.3	0.73	2.88
	2	64.5	1.32	5.03
	3	71.2	1.71	4.86
RRIM 632	1	61.8	0.61	2.97
	2	65.1	0.92	4.22
	3	70.5	1.68	7.04
RRIM 701	1	61.3	0.49	2.09
	2	70.7	2.19	4.96
	3	67.4	2.56	6.51
RRIM 707	1	60.3	0.98	3.82
	2	60.5	1.46	5.17
	3	63.3	1.59	3.80
PB 5/51	1	53.0	0.35	1.78
	2	60.0	0.43	1.67
	3	57.5	0.67	2.48
Ch. 30	1	—	—	—
	2	63.6	1.19	6.31
	3	66.7	1.90	9.51

†Percentage differences were calculated by dividing the maximum differences by the average of the linear and curvilinear estimates and then multiplied by 100.

clones were examined by testing the homogeneity of the constants – c's and d's (slopes and intercepts) among them for the linear relationship.

Taking in the first instance the slopes or the regression coefficients of the different clones for each of the three years, it is seen that the differences among the slopes of the ten clones are highly significant in each of the three years (clone Ch 30 was omitted for the first year). This can also be seen visually in *Figure 4* where the linear relations for the ten clones have been drawn together for each of the three years. It is seen that clones RRIM 501 and RRIM 614 have relatively higher, and PB 5/51 lower, slopes than the others in all three years. Significant differences in slopes from the main body of clones *(Figure 4)* are attained only with RRIM 707 in the first year, PB 5/51 in the third and RRIM 501 and RRIM 614 in all three years.

For each of the clones, the year-to-year differences in the slopes of the regression lines have also been considered. The residual variations generally are not homogeneous for the three years for each of the clones *(Table 3)* but this has been ignored in the testing of the homogeneity of the slopes. It is apparent that

TABLE 6. ESTIMATED YIELDS (G) FOR FIRST YEAR OF TAPPING AT 18- AND 20-INCH GIRTHS AND THEIR RATIOS USING CURVILINEAR *RELATIONSHIPS FOR DIFFERENT* CLONES

Clone	Girth		Ratio† (%)
	18 in.	20 in.	
RRIM 501	14.2	19.8	71.9
RRIM 603	9.6	13.0	73.9
RRIM 607	11.3	15.4	73.3
RRIM 614	16.8	22.3	75.7
RRIM 623	12.1	15.2	79.9
RRIM 632	9.3	12.2	76.1
RRIM 701	12.6	15.7	80.2
RRIM 707	10.2	14.4	70.8
PB 5/51	15.3	18.1	84.6
Ch 30	–	–	–

$$†\text{Ratio} = \frac{\text{Estimated yield at 18 in.} \times 100}{\text{Estimated yield at 20 in.}}$$

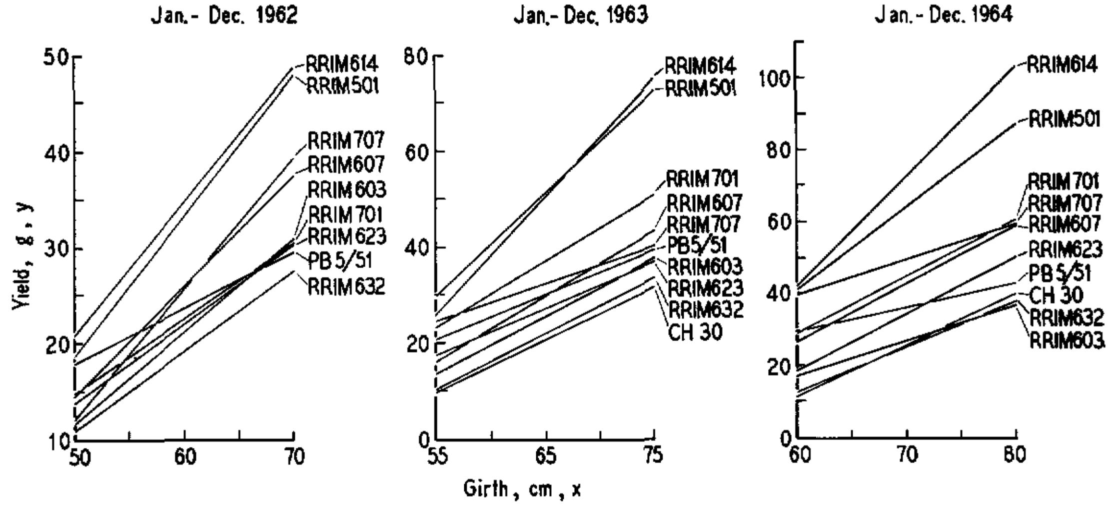

Figure 4. Linear relationships between yield and girth of individual trees for different clones.

the tendency in most clones is for the slope of the yield/girth relationship to increase with age (*i.e.*, for the productivity per unit girth to increase), the difference with clones RRIM 614, RRIM 623, RRIM 632 and RRIM 701 being significant. Only in RRIM 707 and PB 5/51, no such trend was apparent. Where slopes were comparable, calculation of the significance of the difference of the intercept using regression of common slope showed the year-to-year differences of '*c*' value with clones to be significant.

It can be said that the relationship between yield and girth of individual trees varies from year to year and also from clone to clone.

ACKNOWLEDGEMENT

The authors are grateful to Mr E. Bellis, Head of Soils Division, for the valuable help and guidance received in the preparation of this paper. The authors also wish to thank Mr Fong Chu Chai, Head of Statistics and Publications Division, and Dr P.R. Wycherley, Head of Botany Division, for helpful discussions, the field assistants at the R.R.I.M. Experiment Station for collecting, Mr K.M. Retnam for compiling the data and Mr Lee Kim Seong for doing most of the computations.

Statistics and Publications and Botany Divisions
Rubber Research Institute of Malaya
Kuala Lumpur *February 1970*

REFERENCES

BOLTON, J. (1960) The response of *Hevea* to fertilisers on a sandy latosol. *J. Rubb. Res. Inst. Malaya*, **16(4)**, 178.

CONSTABLE, D.H. (1955) Girth and growth measurements as an aid to manurial diagnosis in tropical horticulture. *Rep. 14th int. Hort. Congr.*, **2**, 1346.

DANCER, J. (1964) The measurement of growth in coffee II. The relationship between components of the shoot and stem diameter at the base on the shoot. *E. Afr. agric. For. J.*, **30(1)**, 21.

PAARDEKOOPER, E.C. (1964) Private communication. Rubber Research Institute of Malaya.

PAARDEKOOPER, E.C. (1953) De proeftuin Parung Pandjang en de voorlopige resultaten der aldaar gelegen *Hevea* selectieproeven *Note 27, Proefstation der C.P.V.*

PEARCE, S.C. (1952) Studies on the measurement of apple trees I. The use of trunk girth to estimate tree size. *Rep. E. Malling Res. Sta. 1951*, 101.

RUBBER RESEARCH INSTITUTE OF MALAYA (1966) *Rep. Rubb. Res. Inst. Malaya 1965*, 25.

SHORROCKS, V.M., TEMPLETON, J.K. AND IYER, G.C. (1965) Mineral nutrition, growth and nutrient cycle of *Hevea brasiliensis* III. The relationship between girth and shoot dry weight. *J. Rubb. Res. Inst. Malaya*, **19(2)**, 85.