Variation in Hevea brasiliensis.

BY

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With one Diagram in the Text.

IT was desired to secure data as to the extent to which variation occurs in the amount of rubber yielded by individual trees of *Hevea brasiliensis*, of the same age and growing under the same conditions, and as to the possible correlation between the yield of rubber and the girth of the trunk.

In addition to data directly relative to the matter just mentioned, the observations which have been made afford information concerning the extent of variation in the rubber content of the latex from individual trees and concerning a number of other points noticed in what follows.

The observations were made in the Federated Malay States. A normal area of plantation rubber trees, 7 years old, was selected. The area was approximately 13 acres in extent and contained 1,338 trees, planted 20 feet square. Of these trees 1,137 were in tapping. The trees comprising the balance of 201, not in tapping, were mostly 'supplies', i. e. trees which had been put in since the area was first planted up in order to fill vacancies caused by disease, pests, wind, &c. These trees were of course younger than the other trees on the area and, owing to overshadowing, had not had a good chance to grow. They were, in fact, all removed in the ordinary course of thinning-out operations on the plantation in question soon after the close of the observations recorded here. Of the 1,137 trees in tapping, 106 were one year behind the remainder in their tapping history; having attained a trunk-girth up to the standard fixed for the commencement of tapping operations about one year later than the rest of the trees. Some of them doubtless represented the original plantings, but others no doubt represented 'supplies'. As no means were available for distinguishing original plantings in this group from 'supplies', and as these trees were being tapped at a lower point on the trunk than the rest, they are not included in the present survey. Of the remainder of 1,031 trees, 20 are not included because of incompleteness of the record or failure of the tappers to cut deep enough. The data refer, therefore, to a population of 1,011 trees, in their third year of tapping, on a normal plantation area of seven-year-old Para rubber. They serve sufficiently well to indicate the extent of

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variation between individual trees, in regard particularly to rubber yield, on an area planted, as all the Eastern plantations have been, from non-selected seed, and to suggest the extent of possible improvement in the yields of plantations which seed selection might bring about.

Variation in the Rubber Content of Samples of Latex.

In order to decide as to whether the rubber content of the latex (the 'strength' of the latex) was sufficiently constant to make it feasible to lighten the burden of collecting yield data from individual trees by measuring volumes of latex instead of taking weights of rubber, the strength of the latex from a number of individual trees in the population was determined. These determinations revealed unexpectedly great variations in the strength of the latex from different trees. A frequency table for the samples of latex from the 245 trees examined is given in Table I. In each case the latex was diluted with an equal volume of water, and coagulated with acetic acid; the coagulum was converted into crêpe, and the crêpe, after being allowed to dry in the air, was weighed.

It was found that the strength of the latex from a given tree was approximately constant on different days,[1] and appeared to be characteristic for the individual tree. Several trees were kept under observation for more than a year; and it was found in these cases that, although, as was expected, the strength of the latex from a given tree changed to a certain extent with the weather, yet a tree yielding at one time latex with a rubber-content clearly higher than the average could be relied upon to yield strong latex at all times (and vice versa),[2] and that, by taking samples of latex from a number of trees over a short period such that weather conditions would not be likely to affect the trees to seriously unequal extents, a very fair comparison of the trees in respect of this characteristic could be made.

TABLE I.

Rubber Content of Latex from 245 Trees of Hevea brasiliensis, Seven Years Old.

Grm. rubber per 100 c.c.	23	24–25	26–27	28–29	30–31	32–33	34–35	36–37	38–39	40–41	42–43	44–45	46–47	48–49	50–51	52–53	54–55
Frequency	4	2	7	11	16	27	44	35	23	32	17	12	5	1	4	3	2

Mean = 36·58 ± 0·25 per cent.[3] σ = 5·86 ± 0·17 per cent. *CV.* = 16·02 ± 0·49 per cent.

[1] The trees were tapped once a day only—in the early morning. It was found that when trees were tapped in the afternoon as well as in the morning the strength of the latex obtained on the second occasion was usually markedly lower than of that obtained on the first.

[2] Cf. Bulletin No. 13, Dept. Agric. Ceylon, 1914.

[3] This figure, it should be noted, refers to seven-year-old trees. The age of a tree is a factor in determining the strength of its latex. The author concluded from a limited number of observations, concerning areas from four to eighteen years old, that, as a tree grows older, the rubber content of the latex yielded by it increases 1–2 per cent. per annum.

The samples of latex included in the table were taken mostly from the larger yielding trees (mean yield 11·8 grm. per diem). The figures did not, however, indicate that there was any correlation between yield and latex strength. The figures may thus be considered as fairly indicative of the whole population in regard to the strength of the latex.

Variation in Yield.

The exact magnitude of the yield of rubber given by any one tree varied at different times, but was found to be, in general, sufficiently constant to allow of a fair comparison of the yielding capacities of the trees on a given area under similar tapping conditions being made by taking the mean of the yields on a number (in these observations, mostly six, but in some cases ten to twelve) of separate days.

It seemed clear that, although the actual magnitude of the yield from a given tree varied to a certain extent at different times, owing to variations in fortuitous circumstances, such as the rainfall, the prevailing humidity, the depth of tapping, the hour at which tapping is performed, yet trees presented characteristic differences in their capacity for yielding rubber, and, at all events in a first investigation, might reasonably be compared in respect of this capacity by taking measurements under conditions such that variations in the fortuitous factors which influence the yield were as far as possible avoided, or affected all trees equally, and by, in addition, basing conclusions for any given tree on the mean of several determinations.

In addition to the evidence as to the comparative constancy of the yield from individual trees, which the considerable body of data summarized below afforded when examined in detail, further evidence in support of this conclusion was secured by keeping a limited number of trees under observation for a longer period than that covered by the main series of measurements. In the case of some of these trees the yield was determined at intervals over a period of two years. It was clear that, although seasonal variations in the yield took place, the yield for a given tree was in most cases approximately constant over such a period. Speaking generally, a tree which was seen to be a high yielder at one time could be relied upon to give a high yield at all times.[1]

Concerning the factors which, apart from the characteristic yielding capacity, affect the yield, the following points are noted:

(*a*) All trees were under the same tapping system (a single V-cut on

[1] This conclusion may be considered as being in agreement with general plantation experience. Trees are sometimes noted as falling off seriously in their yield or even as 'going dry'. (It is possible that such behaviour may be due to disease or other abnormal conditions.) But, in general, it is recognized that high yielding trees (which naturally come under notice more frequently than other trees) can be expected, if not over-tapped, to give high yields during the whole of their tapping history.

Also cf. the records for the original generation of trees raised from the seeds first introduced into the East from Brazil: Bulletins Nos. 4 and 13, Dept. Agric. Ceylon.

half the circumference, reopened every morning) and had had the same tapping history. They had been tapped for two successive years on the two halves of the 'basal' section of the trunk, i.e. the portion extending vertically from, say, 20 in. to 4 in. from the ground. In the succeeding year of tapping, when the observations were made, they were tapped on the section of the trunk immediately above the 'basal' section, i.e. the section from, say, 36 in. to 20 in. from the ground. On all trees the tapping cut had advanced roughly the same distance down the section, viz. 6–8 in., at the beginning of the survey.

Thus the height of the tapping cut on the trunk did not enter, as a disturbing factor, into the observations.

(*b*) The trees were tapped by an experienced gang of tappers[1] by means of the simple gouge. The depth of the tapping on each tree was tested by a probe on each occasion that latex was collected from it. In the case of trees where the tapping was clearly not deep enough, the latex was not collected, and an instruction was issued to the tapper to go deeper in the future. The percentage which had thus to be dealt with was not very large. Finally, the records showed a small number of trees on which the tappers had not succeeded in going sufficiently deep, and, as already mentioned, these were excluded from the population surveyed.

It may be considered that the depth of tapping on the trees surveyed represented the greatest accuracy in this direction which is practically attainable.[2]

(*c*) In order to avoid as far as possible the disturbing effect on the comparison of variation in weather conditions, not only was the figure for the yield from each tree based on several measurements, but the times at which the measurements for each tree were taken were distributed at different points over the period of the observations. The period of the year at which the trees lose their leaves was avoided for the observations, as trees are very unequally affected by this 'wintering'. The observations were made over what may be regarded as four typical months in the

[1] It may fairly be mentioned that the native tappers show a degree of skill with the tapping gouge and an accuracy in excising thin strips of bark greater than any to which the author, personally, could lay claim.

[2] An attempt was made to classify the trees according to the degree of exactness with which the fullest possible depth of tapping consistent with avoidance of injury to the cambium had been attained, by estimating the extent to which further latex, if any, issued forth on probing at the tapping level; but it did not prove to offer any particular advantage in regard to the main object of the investigation. It appeared that, excluding the cases already mentioned in which the tapping was palpably not deep enough, the trees, on the one hand, which would, on the ground that deepening of the incision entirely failed to give more latex, be classed as being tapped fully deep enough were in general those giving small yields, and the trees, on the other hand, which would, on the ground that deepening of the incision gave somewhat more latex, be classed as not being tapped quite deep enough were in general those giving large yields. Thus, it may be remarked, a still more exact adjustment of the tapping depth than that actually attained would merely have had the general effect of increasing the contributions from the large yielders, and hence of making still more clearly marked the characteristic features of the variation noted later.

Malay States, viz. August–November. The element in the weather which most markedly influences the yield is the rainfall, the trees yielding better in wet than in dry weather. The daily rainfall on the area during the course of the observations was recorded. The monthly totals were: Aug., 4·73 in. (rain on 13 days); Sept., 12·83 in. (18 days); Oct., 6·72 in. (17 days); Nov. 9·46 in. (17 days).

The results obtained for the rubber yield from the trees surveyed are summarized in the following frequency table:

TABLE II.

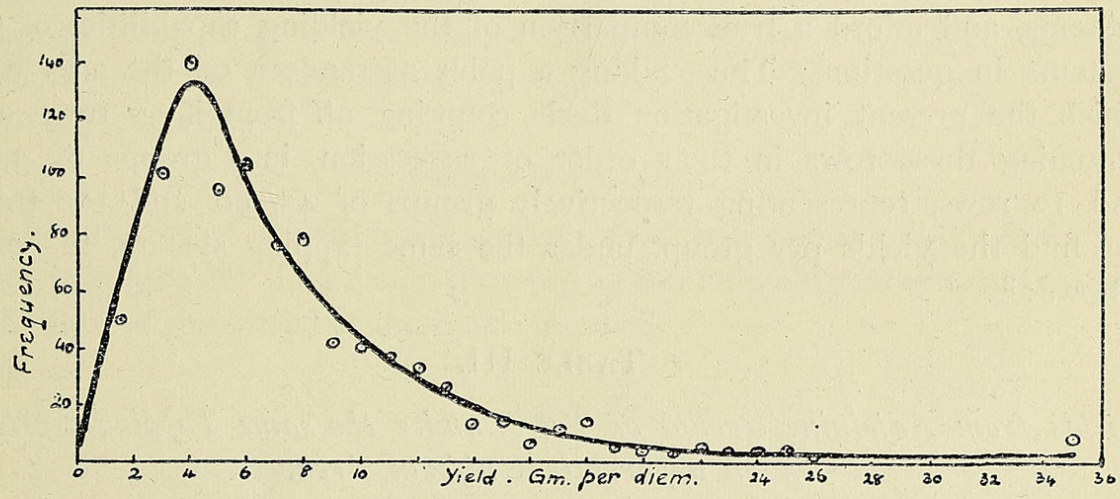
Rubber Yield from Population of 1,011 Seven-year-old Hevea brasiliensis.

Grm. per diem	0–1·5	2	3	4	5	6	7	8	9	10	11	12	13	14
Frequency	55	84	101	140	95	104	76	78	42	41	37	34	26	13

Grm. per diem	15	16	17	18	19	20	21	22	23	24	25	26	27 and over [1]
Frequency	15	7	11	14	5	4	3	4	4	3	4	2	9

Mean yield = 7·12 ± 0·115 grm.[2] σ = 5·425 ± 0·08. Mode (by inspection) = 4·0 grm. *CV.* = 76·19 ± 1·14 per cent. Coefficient of skewness (on σ) = +0·575.

The results are represented graphically in the following diagram:



The outstanding feature of the variation in rubber yield among the population examined is sufficiently indicated by the high coefficient of variability, and the marked positive skewness of the frequency curve, viz. the presence of an important number of trees which are yielding amounts of rubber several times larger than the modal value.

[1] Mean of this group, 35·74 grm.

[2] Equivalent to 5·49 lb. per tree per annum. Making due allowance for the effect of wintering, for the time occupied by the establishment of wound response, &c., this figure accords fairly with the yield of 360 lb. per acre per annum which the section of the plantation in question was giving over all.

Lump rubber, i. e. natural coagulum which forms in the collecting cups, is included in the yields recorded, but 'tree scrap', i. e. rubber obtained from the latex which is left on the cuts after the trees have ceased to drip, is neglected. The average amount of tree scrap which each tapping gives is indicated by the following figures: (*a*) 195 trees gave 134 grm. tree scrap; (*b*) 190 trees gave 115 grm. tree scrap.

It may be remarked, for example, that 9·6 per cent. of the trees (trees giving twice the mean quantity or more) was on the average yielding 3·6 times as much rubber per tree as the remainder of the trees. On the one hand, 9·6 per cent. of the trees on the area was contributing 28 per cent. of the total yield. On the other hand, 13·7 per cent. of the trees (Groups 0–2 gms.) was contributing only 2·9 per cent. of the crop, and certainly did not repay the cost of tapping. The highest yielders in the population were four trees giving the following yields per diem: 41·45, 41·56, 41·72, 42·77 [1] grm.

The great possibilities of seed selection in improving rubber yields are indicated by the above figures.

The data obtained have a certain bearing on the conduct of tapping experiments. They show that the extent of variation on what is presumably a normal area may be such that it is quite impermissible to assume, as is often done in tapping experiments, that small groups of trees (say 50 or 100 trees) chosen at random from an area of uniform age, situation, and appearance, will have the same yielding capacity, and hence that differences in yield which the groups may display when different tapping systems are applied to them are due to differences in the tapping systems, and afford a true comparison of the yielding capabilities of the systems in question. Thus, taking a point at random on the area with which the present investigation deals, counting off from it 36 rows, and arranging these rows in their order of succession, into groups of 3, 6, and 12 rows, representing respectively groups of 45, 90, and 100 trees we find the yields per group, under the same tapping system, to be as follows: [2]

TABLE III.

Yields from Adjoining Groups of Trees, under the same Tapping System, on an apparently Uniform Area.

	Grm. rubber per diem.
Group of 45 trees.	284, 285, 204, 259, 260, 334, 392, 439, 328, 390, 325, 276.
„ „ 90 „	569, 463, 594, 831, 718, 601.
„ „ 180 „	1032, 1425, 1319.

[1] Equivalent to a yield (calculated without making allowance for the reduction which 'wintering', &c. involves) of 33 lb. for a tapping year of 350 days.

It may be remarked that at an earlier point in its history one of these four trees had, according to the estate records, been treated against an attack by white ants. It would seem certain, however, that the high yield which it displayed during the period of the present observations was not due to white ants, because (*a*) careful examination failed to reveal the presence of white ants and the tree was certainly alive two years after the observations had been concluded, (*b*) the greatly increased flow of latex which white ants are recognized as inducing is transient, whereas the present tree was found to give large yields over a period of two years during which it was kept under observation.

[2] The most frequent number of trees in a row was fifteen. In cases where the number was other than this, the yield for the row has, for the sake of simplicity, been adjusted proportionately.

A number of observations were made on the problem of collecting seeds from selected trees.

Owing to the circumstance that the seeds are often projected to considerable distances from a tree when the ripe capsules burst, the seeds lying on the ground under a given tree are not usually all derived from the tree in question. In order to secure seeds whose origin was definitely known, the author at first placed conical bags of wire-netting round the capsules on the selected trees; but it was later found sufficient to secure one true sample of the seeds from a given tree, as it was observed that the seeds from any one tree were exactly similar in appearance.[1] The differences which the seeds from different trees exhibit in regard to tint, mottling, and size,[2] are very marked, but perhaps even more noteworthy than such differences is the accuracy with which the tint, the mottle-pattern, and the shape, down to such peculiarities as slight striations on one side, are repeated in all the seeds from a given tree. With a little experience it was found possible, once a true sample had been secured to act as a pattern, readily to pick out the seeds from a given tree from those lying on the ground in its neighbourhood. It was often possible to avoid the trouble of placing a number of wire-netting bags on the tree for the purpose of securing a true sample by keeping the tree under watch for a short time on a hot afternoon at the period when the capsules were bursting in numbers.

Variation in Girth.

The girth of the trees was measured at two points: 22 in. and 36 in. from the ground. The girths recorded in the following frequency table are the mean of the girths at these two points.[3]

TABLE IV.

Girths of Population of 1,011 Seven-year-old Hevea brasiliensis.

Girth in cm.	50–52	53–56	57–60	61–64	65–68	69–72	73–76	77–80	81–84	85–88	89–92	93–96	97–100	101–104	105–108	109 and over.
Frequency	2	12	29	49	70	106	114	146	127	114	91	60	49	20	8	14[4]

Mean girth = 80·30 ± 0·25 cm. σ = 11·91 ± 0·18. *CV.* = 14·85 ± 0·22 per cent.

[1] For a similar observation made in Brazil, cf. Cramer: Rubber Recueil, Amsterdam, 1914, 12.

[2] For data on the variation in weight and size, see Sprecher: Bull. Jardin Botanique de Buitenzorg, No. 19, 1915, p. 112.

[3] 22 in. from the ground represents the lower level and 36 in. from the ground the upper level of the section of the trunk which was being tapped during the year in which the observations were made. 22 in. from the ground is also the level frequently fixed for measuring the girth of trees in order to decide whether they are large enough for tapping; and it may therefore be stated that the mean girth given in the table was on the average 5·75 per cent. less than the girth measured at 22 in.

[4] Mean of this group, 113 cm.

The girth data, like the data for latex strengths, appear to present a normal distribution.

Correlation between Yield and Girth.

The question of the extent to which the girth of the trunk is indicative of the rubber yield of a tree has considerable practical significance. If the correlation results showed that it is justifiable to assume that there is a high degree of probability that a tree with a small trunk will give a poor yield, and a tree with a large trunk a good yield, the work of selecting trees, in regard to their yielding capacity, for thinning-out operations would be greatly facilitated.

The figures given below indicate that, although there is a definite positive correlation between yield and girth, the extent of the correlation is not sufficient to justify very much emphasis being placed on girth when selecting trees for thinning out.

TABLE V.

Correlation between Yield and Girth in a Population of 1011 Seven-year-old Hevea brasiliensis.

Yields, grm. per diem.

Girth, cm.	0–2	3–4	5–6	7–8	9–10	11–12	13–14	15–16	17–18	19–20	21–22	23–24	25–26	over 26	
50–52	1	1													2
53–56	5	3	2	1	1										12
57–60	8	11	3	5		1	1								29
61–64	14	15	8	6	3	2	1								49
65–68	13	24	16	6	3	4	2	1						1	70
69–72	16	30	25	17	7	5	2	2	1	1					106
73–76	17	28	19	17	11	14	2	2	1		2			1	114
77–80	17	36	32	21	14	11	8	4	1			1		1	146
81–84	16	27	29	23	8	6	5	1	6	2		1	2	1	127
85–88	13	28	21	16	8	9	5	2	5	3	1			3	114
89–92	8	17	18	19	9	6	3	1	6	1		2		1	91
93–96	5	9	10	12	8	4	1	3	1		3	1	2	1	60
97–100	3	8	9	4	5	6	5	3	3	1		1	1		49
101–104	2	2	5	2	2	3	1	1	1				1		20
105–108				3	3		1					1			8
109–124	1	2	2	2	1		2	2		1	1				14
	139	241	199	154	83	71	39	22	25	9	7	7	6	9	1011

$r = +0.260 \pm 0.020$.

In addition to the characters which have been mentioned as showing, for a given tree, approximate constancy, certain peculiarities were observed in the cases of particular trees, which were also constant over considerable periods of observations, and which may probably be regarded as characteristic of the trees displaying them. Such were the following :

(*a*) Rapid discoloration of the latex. Rapid oxidative discoloration of the latex may be associated merely with insufficiently deep tapping. Thus

it may not infrequently be observed that the latex left on the tapping cut, after a tree has ceased to drip, darkens rapidly at the upper end of the cut, where there is a strong tendency for the tapping to fall short of the proper depth. But, quite apart from cases of rapid discoloration which could be avoided by deeper tapping, it was observed that in some cases rapid discoloration appeared to be characteristic of the tree. One tree, which showed this feature very strikingly, was kept under notice for five years, and was always seen to produce rapidly-discolouring latex, which gave an exceptionally strong reaction for peroxidase.[1]

(*b*) Tendency to rapid coagulation. In the case of two trees in the population with which this communication more particularly deals, a tendency to exceptionally rapid natural coagulation was observed in the latex, and persisted over a considerable period.

(*c*) A marked cream-straw colour appeared to be characteristic of the latex from a small percentage of trees. (This colour is to be distinguished from the transient yellow colour which latex from a new cut often has before wound response has established itself.) The latex in question has a noticeably 'rich' appearance. It was not, however, found in general to have a higher rubber content than the average.

POSTSCRIPT.—Since the above was in print, A. A. L. Rutgers [2] has given some interesting data which are in full accord with the observations (made in 1913), recorded in the present paper, as to the practical constancy of the yield from individual trees and as to the character of the distribution of the total yield over a group of rubber trees of equal age. Data for three areas are recorded by Rutgers.[3] As a result of comparing the classification of the trees made at the outset with that made ten to twenty months later, he concludes that 'good trees remain good, poor trees remain poor'. From his data for a group of 1,467 trees (mean daily yield per tree, 9·1 g.) it may be calculated that, at one extreme, 9·0 per cent. of the trees (trees giving 17 g. or more) produced 23·9 per cent. of the total yield, and, at the other extreme, 27·3 per cent. of the trees (trees giving 0–5 g.) produced only 7·2 per cent. of the total yield.

[1] Cf. Whitby : Koll. Zeit., 1913, vol. xii, p. 147.

[2] Selectie en Uitdunning. Archief voor de Rubbercultuur, 1919, 3, 105–123.

[3] It may be remarked that in the case of two of these areas the volume of latex, not the weight of rubber, per tree was the quantity measured. Also, in the instructions with regard to the collection of yield data for the purpose of selecting trees for thinning-out operations, it is directed only that the volume of latex shall be determined. It would seem, however, from the results recorded in the present paper on the 'Variation in Rubber Content of Samples of Latex', that this simpler procedure does not give exact results, and that it is necessary to weigh the rubber.