

INVESTIGATION INTO THE RELATION BETWEEN THE DIAMETER OF THE LATEX TUBES AND THE RUBBER PRODUCTION OF *HEVEA BRASILIENSIS**

INTRODUCTION

The theory of Ashplant.—During the last two years H. Ashplant has developed a theory, according to which it would be possible to distinguish with practical certainty high-yielding rubber trees as early as in the nursery stage, so that useful superior planting material could be selected from a very heterogeneous mixture. Ashplant's statements are founded on assumptions, which can be summarized as follows:

1. In a Hevea tree a very striking correlation exists between the yield capacity and the diameter of the latex tubes. This correlation is considerably better than the relation found between the number of latex rings and the yield of rubber.

2. A hevea tree with latex tubes with large diameter in the bark also has large bore tubes in the leafstalk.

3. The size of the diameter of the latex tubes in an individual tree is constant during the whole duration of life, from its earliest youth (6 months old), and hereditary.

From these hypotheses the conclusion is drawn, that a single cut through the leafstalk of a 6-month-old Hevea seedling suffices to decide in all probability whether the tree, when tappable, will be a good or a poor yielder. Unfortunately no proof is adduced for the second and third of the above-mentioned hypotheses, whilst the first is supported by two correlation tables in Ashplant's third publication. In our opinion it is however an omission that not one of the three preliminary papers mentions how the diameter of the latex tubes can be measured with the degree of accuracy given in the correlation tables.

Since this new method of selection would be invaluable for practical purposes, an investigation was started to test this theory after the third publication (December 1928) had not given the detailed description, repeatedly promised, of the method to be used. The more so since on theoretical considerations, mentioned hereafter, a very striking correlation between the diameter of the latex tubes and the production can be expected.

As a consequence of lack of data in his publications it was impossible to adhere to Ashplant's method of working, so that we had to work out our own method of measuring (section 5). It follows that this treatise can only aim at a control of Ashplant's fundamental idea, and unfortunately it is not possible to make a comparison with the figures obtained by him according to an unknown method.

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Unfortunately the greater part of the available time was spent in working out a flawless micro-technique for the measuring of the diameter of the latex tubes; consequently the number of trees of which measurements have been recorded is comparatively small; notwithstanding this fact the data are convincing. With a view to the complaints which have been worded of late on the lack of a satisfactory method of measuring, the author considers it desirable to publish his records in order to save investigators from such a loss of time in working out a satisfactory technique.

1. THEORETICAL CONSIDERATIONS

1. *The volume of latex tubes.*—When estimating the value of rubber tree according to the quantity of rubber contained in the stem, by considering the volume (1) of the latex tube system, as done by Bendixen it is at once evident that the diameter of the latex tubes plays a far more important part than all other factors which come under consideration.

Assuming that the latex tubes are straight capillaries, the volume of a cylindrical stem (budding) is:—

$$V = n \cdot a \cdot o \cdot r^2 \cdot l \quad (1)$$

in which n = number of latex rings

a = number of latex tubes per 1 c.m. of ring

o = circumference of the tree in c.m.

r = radius of the latex tubes in c.m.

l = length of the stem in c.m.

This equation shows that the volume is proportional to be the square of the radius of the latex tubes, whilst all other factors such as the number of rings (n) the circumference (o) etc. only occurs in the first power.

The presumption that the tubes are straight capillaries is however incorrect, since they form a network. Therefore the volume is more accurately determined by measuring the area of 1 sq. cm. of the network by means of a planimeter. The figure thus obtained is a measure for the denseness of network and can be used in the equation (1) instead of $a \cdot r$. The volume is still proportional, though indirectly, to the square of the radius of the latex tubes.

It follows that a tree, which has latex tubes with a diameter twice as large as those of another tree with an equal number of rings, the same circumference etc., contains four times the quantity of latex found in the tree with smaller tubes. This is evidently in favour of the theory of Ashplant.

But actually a yielder should not be classified according to the volume of its system of latex tubes; for what is the value of a considerable quantity of latex if it does not flow out easily and to a satisfactory extent? Tapping is a dynamic problem and static considerations are not worth much, if we try to obtain the latex from the bark, although naturally the quantity of latex in the whole system of tubes comes under consideration as a reservoir for the issuing latex.

3. *Dynamics of the latex flow.*—Liquid moving in narrow tubes follow the law of Poisseuille. According to this law the volume V which flows from a tube during the period t is:

$$V = \frac{\pi \cdot p \cdot r^4}{8 \cdot l \cdot \eta} \cdot t \quad (2)$$

in which p = internal pressure in the tube

r = radius of the tube

l = length of the tube

η = internal friction (viscosity) of the liquid

n = internal friction (viscosity) of the liquid

t = period of flow.

For the latex tubes, (p) is the turgor in the system of tubes and (l) stands as a measure for the area drained; *i.e.*, the area in which the latex flows in the tubes with a given velocity. The observations of De Vries give an idea of the internal friction (viscosity) of the latex; for the equation of Poisseuille however the absolute value is required and not the relative value.

Taking into consideration the number of latex tubes opened by the tapping cut, the following volume of latex V can be expected:

$$V = \frac{n' \cdot a \cdot o}{3} \cdot \frac{\pi \cdot p \cdot r^4}{1 \cdot \eta} \cdot t \quad (3)$$

where (a) and (o) have the same meaning as in equation (1) (only $\frac{1}{3}$ of (o) comes into consideration), whilst (n') no longer stands for the total number of rings, but for opened "productive" rings (see section 10).

It goes without saying that no absolute value can be given to this relation, since the latex tubes are not straight capillaries and the problem of flow is so complicated on account of the numerous anastomoses which interconnect the tubes, that it hardly admits of a mathematical solution; moreover the magnitudes (p) (l) and (η) change during tapping. However equation (3) gives an insight into the relation between the quantity of latex of flowing out and the various factors. It is to be expected, therefore, that the quantity of latex produced during tapping will be proportional to the number of "productive" rings (n') the number of tubes per cm. of ring, the circumference (o) the turgor (p) the period of flow (t) and in inverse proportion to the length (l) through which the latex is pressed. On the other hand the quantity of latex flowing out will increase with the fourth power of the diameter of the tubes! A tree with tubes twice as wide as those of another tree, comparable in all other respects would produce 16 times as much latex than latter. Only if four different factors in equation (3) were doubled simultaneously (l and η divided by 2) would the yield of the second tree equal that of the first. This being precluded, it follows that the diameter of the latex tubes is theoretically the predominant factor in the latex flow, and therefore the theory of Ashplant seems to be remarkably well founded.

2. METHOD OF INVESTIGATION

3. *Suggestions for the investigation.*—Whilst Ashplant discusses his theory at great length, the reader is left absolutely in the dark as regards his technique, the data on this being very scanty.

From the discussions of his theory in the literature it is permissible to conclude that he uses a projection apparatus for measuring; it is even mentioned that accurate measuring would be impossible without the use of this apparatus. On the other hand we have the fact, known to every investigator well versed in handling the microscope, that projecting does not increase the accuracy of the microscopic image. If for instance the diameter of a cell can be measured in the microscope with an accuracy of 5%, the projection, enlarging the microscopic image a hundred-fold, does not permit measuring with any greater accuracy, since all optical errors of the image are also enlarged a hundred-fold, the contours grow vague and so on. The accuracy of the projected image is only deceptive. Lengths smaller than $\frac{1}{2}$ wavelength of light (0.2-0.3 μ) are not shown true to life and are not measurable, whilst on an enormously enlarged projected image, measuring is apparently possible with an accuracy up to 0.05 μ and even more "accurately." It cannot be denied that an efficient micro-projector

is of great value for showing slides objectively to an audience, for drawing or in order to use the planimeter, but for measuring linear lengths it functions no better than any good microscope. For measuring, a projector can therefore be discarded and an ordinary microscope will suffice.

Further it is important how the yield of the trees is determined. In Ashplant's correlation tables the trees are classified according to their latex yield in cubic centimeters. But since for selection purposes the production of dry rubber, which is often not proportional to the latex yield, plays a prominent part. It seems more accurate to judge the trees according to their yield of dry rubber.

Ashplant maintains silence as to the micro-technique with the exception of a remark that only longitudinal selections can be used. It is necessary therefore to work out an independent method. For this investigation 2 methods were tried on material fixed in alcohol (70%).

1. Schulze's maceration method.
2. The eau de Javelle method.

Since the method used by Ashplant is not known, unfortunately comparisons of the figures derived from this investigation with those of Ashplant are necessarily subject to qualification, especially since the yield measurements are based on another principle. The object of this investigation is therefore restricted to investigating the existence of a correlation between rubber production and latex tube diameter.

4. *Objections to the maceration method for the purpose of measuring.*—Although the maceration method is admirably suited to the study of the course of the latex tubes in the bark and for counting the rings, it cannot however come under consideration for the purpose of measuring, since the tubes swell as a result of the treatment and, later on, when the sections are stored in glycerine, gradually become thicker. This is proved by a comparison with measurements of sections treated with eau de Javelle (table I). The sections are derived from the same bark sample; the figures are the average of 100 measurements each.

Table I

Comparison between the maceration and eau de Javelle methods

Position of the trees in Soengei Pantjoer	Diameter of the latex tubes of the bark in μ	
	Maceration method	eau de Javelle method
Block Row Tree		
crosses 165 x 161		
8 6 1	26.7 \pm 0.30	23.8 \pm 0.20
8 6 4	28.2 \pm 0.53	27.0 \pm 0.36
8 6 6	27.9 \pm 0.36	24.7 \pm 0.26
marcots clone 180		
9 14 8	25.6 \pm 0.34	22.9 \pm 0.28
9 14 10	27.6 \pm 0.48	23.3 \pm 0.25
9 14 12	26.6 \pm 0.38	22.7 \pm 0.27

It appears from table I, that the macerated sections have much broader latex tubes than those obtained by eau de Javelle procedure; further the maceration method results in considerably large standard deviations.

The trees from block 8 are seedlings from the cross 165 × 161 (see section 8a) and the three trees from block 9 are marcots from clone 180. According to the third hypothesis mentioned in the introduction the latter should have the same width of latex tubes. Whilst this is more or less the case, within the limits of the standard deviation, for the sections treated with eau de Javelle, such a relation cannot be concluded from the maceration method.

After one month a few measurements on the same sections were repeated; the tubes treated according to Schulze appeared to have swollen still more:

Block	Row	Tree	1st measurement	2nd measurement
9	14	8	25.6 ± 0.34	27.1 ± 0.53
9	14	12	26.6 ± 0.38	28.0 ± 0.38

In the sections treated with eau de Javelle only variations within the limits of the standard deviation were found.

It appears from these facts, that the maceration method is impracticable for accurate measurements, whilst on the contrary the eau de Javelle method can be used, if measuring is done within one month. This being always feasible, investigation along this line was discontinued.

In order to know the diameter of the latex tubes measuring should be done from cell wall to cell wall. Now this is very difficult if only the cell content is coloured and when hundreds of measurements must be recorded this work is a strain on the eyes. Especially with the maceration method, when the cell walls are nearly indiscernible, the coagulated cell content is measured involuntarily instead of the diameter. But the coagulated rubber is irregularly withdrawn from the cell wall so that the figures found for the diameter of the latex tubes are too small. Sections treated with eau de Javelle can be used much better for staining the cell walls than those treated with potassium chlorate, as the latter disintegrate easily because the tissues no longer cohere.

5. *The method employed for the present investigation.*—After the preliminary investigation had shown that the eau de Javelle method yields better results than the maceration method and that staining of the cell wall is necessary, the following technique was developed. The sections, which should not be too thin (otherwise the latex tubes are torn), are cut with a gliding microtome and treated as follows:

- Bleached in eau de Javelle for 1 hour,
- Stained in Delafield's haematoxyline for 5 minutes (or less),
- Rinsed in water and immersed in glycerine,
- Stained in Sudan III for $\frac{1}{2}$ hour,
- Rinsed in glycerine.

Eau de Javelle, being unstable in the tropics, is prepared and continually kept fresh in the following manner: chlorine is generated from pyrolusite and concentrated hydro-chloric acid and led through a dilute solution of potassium hydroxide (10-15%). Since chlorine is liberated at tropical temperatures heating is not necessary. In this way it is possible to obtain a slight and fairly regular flow of chlorine from granulated pyrolusite (manganese dioxide), which is led day and night through the potash lye in a fumecupboard. In this way a strong eau de Javelle is always available, bleaches the sections within one hour.

Sudan III is prepared according to the formula of Bobilioff and Delafield's haematoxyline according to Strausburgher.

When the sections are satisfactorily stained the walls of the tubes are intense blue and the coagulated cell content a brilliant red. It is then clearly seen that the cell content is irregularly withdrawn from the cell wall. Therefore alcohol (70-90%) is not an ideal fixative for the system of latex tubes. The whole cavity was always measured from cell wall to cell wall.

6. *Anatomy of the petiole of Hevea.*—Preparatory to carrying out measurements on a large scale an investigation into the anatomy of the petiole was considered indispensable, since that is missing in Bobilioff's paper and Ashplant has not investigated whether the system of latex tubes in the bark of the stem is different; neither does he mention that two kinds of latex tubes occur in the leafstalk.

It follows from the anatomical investigation, that only the tubes between the tissue of the pericycle and the wood cells should be considered for measuring. Since these tubes have been formed in a different manner (according to their origin they are to be considered proto—or metaphloëm elements) to the latex tubes of the stem bark (secondary phloëm elements), it is anatomically incorrect off hand to consider the former equivalent to the latter.

3. MEASUREMENTS MADE

A Zeiss microscope with objective D (=40) and compensating ocular 18 as ocular micrometer were used for measuring. One interval of the micrometer corresponded to 4.7μ . Since the diameter of the latex tubes varies considerably, it was especially necessary to know the number of measurements required for a reliable average. Ashplant used the average of 120 measurements; but since he does not give standard deviations, no idea of the extent of the variation of the diameters of the tubes is obtainable. Each of the figures in the following tables is the average of 100 measurements; it appears from the standard deviations that this number is sufficient. Quite valueless averages would be obtained, however, if, in order to save time, less numerous measurements were taken, for instance 10. In this case the standard deviation would increase threefold, so that the averages in table II would not represent an actual difference.

7. *Measurements in leafstalks of buddings of known clones.*—Of course the most remarkable statement of Ashplant, that seedlings scarcely 6 months old with large tubes will become good yielders when tappable, is impossible of verification at present. On the other hand this could be done with 6 months old buddings from known clones. For this purpose leaves were harvested in the nurseries from the AVROS-clones mentioned in tables II and III, fixed in alcohol and after a few days treated as described in section 5. In order to get comparable material the lowest leaves from full-grown internodes were chosen exclusively.

6 to 10 sections were put on a slide in glycerine. Of course sections which have been cut somewhat tangentially contain more tubes than true radial sections. To begin with, an investigation was carried out to discover whether 100 measurements, made repeatedly in the same preparation, always resulted in the same average.

This preliminary investigation was carried out with two clones and resulted in the following data (see table II):

Clone		Average of the 1st- 100th measurement	Average of the 101st- 200th measurement
152	...	$17.6 \pm 0.25 \mu$	$17.7 \pm 0.34 \mu$
180	...	$18.1 \pm 0.33 \mu$	$18.2 \pm 0.34 \mu$

The averages of each 100 measurements¹ are seen to agree with the limits of the standard deviation.

In order to give an idea of the variations in width of the latex tubes in the leafstalk (and analogously also in the bark), the distribution of each 100 measurements is given in table II arranged in classes of $\frac{1}{2}$ micrometer divisions.

When all measurements in each class are added up, figures are obtained which correspond with a fairly regular Galton's curve. Consequently the material examined does not contain many very large or very small tubes.

In table II the clones are ranked according to the diameter of the latex tubes; the differences are not very marked. But it is very curious, that our contra selection tree, clone 180, which scarcely yields any latex when tapped, possesses the same diameter as clone 36, one of the highest-yielding clones. Unfortunately we do not possess more poor but well-known clones to determine whether this is only a fortuitous exception.

Comparing the diameters with the yields of the various clones, a good correlation is not found (table III). It is true the good clones 256 and 71, as well as the promising clones 183 and 214 head table II, but on the other hand the rather widely varying clones 33, 80, 152 and 163 have the same diameter of the latex tubes, whilst the good clones 49 and 50 come at the bottom of the list and below the indifferent clone 35.

Table II

Distribution of frequency of 100 measurements of the diameter of the latex tubes in leafstalks of known clones. 1 division (d) of the micrometer = 6.7 μ

Clone	Number of measurements										Average	
	d = 2	2½	3	3½	4	4½	5	5½	5¾	6	in d	in μ
256	—	2	9	17	31	22	15	4	100	4.11 ± 0.068	19.3 ± 0.032	
183	—	2	13	20	27	26	12	—	100	3.99 ± 0.064	18.8 ± 0.30	
71	—	1	10	26	35	16	10	2	100	3.96 ± 0.062	18.6 ± 0.29	
214	—	2	15	23	33	16	10	1	100	3.90 ± 0.064	18.3 ± 0.30	
36	—	2	14	32	33	14	5	—	100	3.79 ± 0.056	17.8 ± 0.27	
152	—	—	22	26	37	12	3	—	100	3.74 ± 0.053	17.6 ± 0.25	
	—	6	17	30	23	14	8	2	100	3.77 ± 0.070	17.7 ± 0.34	
163	—	1	16	37	33	11	2	—	100	3.71 ± 0.049	17.5 ± 0.23	
80	—	1	20	33	32	9	5	—	100	3.71 ± 0.055	17.5 ± 0.26	
33	1	5	22	24	27	14	7	—	100	3.70 ± 0.067	17.4 ± 0.32	
35	—	2	17	38	32	10	1	—	100	3.67 ± 0.049	17.3 ± 0.23	
49	2	9	29	24	19	15	2	—	100	3.51 ± 0.067	16.5 ± 0.32	
50	—	5	29	34	28	4	—	—	100	3.48 ± 0.048	16.4 ± 0.23	
	3	38	233	364	390	183	80	9	1300			
Contra selection tree 180	—	5	17	21	30	15	10	2	100	3.85 ± 0.071	18.1 ± 0.33	
	—	7	16	20	24	20	13	—	100	3.85 ± 0.073	18.2 ± 0.34	
	—	12	33	41	54	35	23	2	200			
Total	3	50	266	405	444	218	103	11	1500			

Table III

Comparison between the yield of known clones (according to Heusser) and the diameter of the latex tubes of the leaf-stalk of 6 months old buddings.

Clone	Grams of dry rubber per tapping year of tapping.						Diameter of the latex tubes of the leafstalk	Position of the trees
	1	2	3	4	5	6		
33	5.5	11.2	23.8	27.6	29.9	31.8	17.4 ± 0.23 μ	Seed garden
35	6.8	16.3	18.3	21.7	26.5	—	17.3 ± 0.23 "	Tjinta Radja
36	4.2	10.0	20.3	24.8	33.2	41.4	17.8 ± 0.27 "	Seed garden
49	6.2	14.5	21.3	25.6	30.7	—	16.5 ± 0.32 "	Tjinta Radja
50	6.1	14.7	30.3	34.0	29.5	31.1	16.4 ± 0.23 "	Seed garden
71	7.8	12.8	21.8	—	—	—	18.6 ± 0.29 "	Boekit Maradja
80	6.3	12.1	15.2	—	—	—	17.5 ± 0.26 "	Boekit Maradja
152	9.7	17.1	23.6	—	—	—	17.6 ± 0.25 "	Boekit Maradja
163	7.8	12.7	20.8	—	—	—	17.5 ± 0.23 "	Boekit Maradja
183	14.8	24.0	—	—	—	—	18.8 ± 0.30 "	Soengei Pantjoer
214	15.2	—	—	—	—	—	18.3 ± 0.30 "	Soengei Pantjoer
256	—	—	—	41.7	—	—	19.3 ± 0.32 "	Temiang
Contra selection tree 180	26	0.6	1.3	—	—	—	18.1 ± 0.33 "	Soengei Pantjoer

Ashplant says that all clones from Java, which he examined showed very wide latex tubes; from correlation table VI it appears however, that the diameters of the latex tubes of the examined clones are not very outstanding, with exception of clone 256. The variability in yield of the clones now examined, with exception of the contra selection tree 180, is too small to allow conclusions to be drawn from the figures, the less so since the clones have been tested in different places so that the yield records are not strictly comparable. Therefore the investigation was extended to seedlings of the most widely varying yield classes.

The small variation in yield of the clones coincides with a small variation in the diameters of the latex tubes. It only amounts to $16.4-19.3 \mu$ (as against $14.4-21.2 \mu$ for the seedlings examined, see tables IV and V), whilst nearly all are classed in the groups of 17 and 18μ (see table VI). Taking into consideration the relatively large standard deviations, which allow only differences of more than 0.5μ to be considered real differences, judging the clones examined according to the diameter of the tubes (excepted perhaps clone 256) seems to be without prospects.

8. *Measurements of latex tubes of seedlings in leafstalk and bark.*— Investigation of tappable seedlings cannot decide the most important problem, to wit, whether Ashplant's method of selection is applicable to nurseries. On the other hand comparative measurements can be carried out in leafstalks and bark, and the correlation between "yield and number of rings of latex tubes" can be contrasted with that between "yield and diameter of the latex tubes."

Leaves were therefore harvested from each tree and at the same time samples were taken of virgin bark at a height of 1 M. The sections of the bark were cut exclusively from the "productive" zone (see section 10), since according to Ashplant a considerable difference exists between the diameter of the latex tubes near the cambium and that of the tubes in the outer zone.

All the seedlings examined were planted in October 1921 as 1-year-old stumps and for the greater part were in the third year of tapping in 1928; all are growing in the Soengei Pantjoer selection garden and their positions are given in the tables.

In tables IV and V the averages of the measurements are calculated at Soengei Pantjoer according to block, row, and tree of the trees examined; for instance 8/12/6 means the sixth tree in row of 12 of block 8. In the following correlation tables (VI-X) all trees are described in the same way; this simplifies looking up the same tree in the various tables. Columns 2 and 3 give the averages of the 100 measurements of tubes in leafstalk and bark with the respective standard deviations. Column 4 gives the ratio between the diameters of the tubes of leafstalk and bark. Columns 5 and 6 give the yield (grammes of dry rubber per tapping) column 5 the average of all three tapping years, and column 6 the average of 1928 (150 tapping days). For the compilation of the correlation tables VI-X the averages of 1928 have been used exclusively since otherwise no comparison with the correlation between number of rings and yield would have been possible, nor could a calculation of the yield per productive ring have been made, because the bark samples taken in the beginning of 1929, can only be used for judging the bark during the last tapping period.

Columns 7 to 10 comprise the number of rings of latex tubes of the bark as specified in section 10. In column 11 the yield of one productive ring has been calculated, and in column 12 that of 1 cm. of productive ring by means of the girth measurements at a height of 1 M., given in column 13; it must be noted that only $1/3$ of the circumference is being tapped.

In the last column (14) the crossings have been mentioned which were chosen as new mother trees, or which have not yet been tapped for three years for some reason or other (slow growth in thickness etc.). These trees have also been measured in this investigation in order to get a greater variation of yield and circumference. If very divergent figures had been obtained from these trees, tending to obscure the results, it would have been necessary to omit them, but since they do not fall beyond, but within, the limits of the good growers and partly (such as trees 43/2/1 and 43/2/2 in tables VI and VIII) contributed to an improvement of the correlation, they have been inserted in the correlation tables VI-X.

a. *Crosses of the family 165 × 161.*—Widely varying yielders are found amongst the crosses of mother tree 165 with No. 161 as father tree. Unfortunately only 4 trees of this cross have reached tappable age, and one is so backward, that it is not considered in this investigation. It appears from table IV, that the large differences in yield coincide with an appreciable variation of the diameter of the latex tubes. Of all examined trees, tree 8/6/4 which has been chosen as a new mother tree 317, has the widest latex tubes (and also for that matter the greatest number of productive rings).

b. *Crosses of the family 157 × 166.*—In the second place 12 trees of cross 157 × 166 with as widely varying yields as possible were measured. Two of these trees have been chosen as new mother tree on account of the satisfactory yield (8/12/11 = mother-tree 292 and 8/12/4 = mother-tree 293); their latex tubes do not stand out with a very large diameter.

c. *Kampong trees.*—An insufficient number of poor yielders occurring amongst the artificial crosses, measurements were taken of 14 of the kampong trees which have been planted in Soengei Pantjoer for comparative purposes. Trees 43/2/1, 43/2/2 and 43/2/9 are backward, or for other reasons have been tapped only one year.

9. *Results of the measurements of the diameter of the latex tubes.*—The ratio between the latex tubes of the leafstalks and those of the bark yields the most important results. Ashplant takes for granted that trees with large tubes in the bark also possess large tubes in the leafstalk, but this assumption is not substantiated by a single figure. According to a report of a planters' meeting the existence of such a correlation would be immaterial to him.

Table IV

Diameter of the latex tubes and of yield artificially crossed trees.

Position in Soengei Pantjoer block/tree row/1	Diameter of the latex tubes in μ		Ratio leafstalk/bark	Production in grammes of dry rubber per tapping		Number of rings of latex tubes				Production 1928 of		Circumference at 1 m height in cm.	Remarks
	leafstalk 2	bark 3		1926/28	1928	total 7	within 1.6 m.m. 8	pro- ductive 9	hard bark 10	1 produc- tive ring 11	1 cm pro- ductive ring 12		
8/12/1	16.4 ± 0.19	26.3 ± 0.35	0.63	5	6	27	6	17	4	1.39	0.055	76	—
2	18.3 ± 0.15	26.6 ± 0.31	0.69	12.5	17.0	37	15	16	6	1.06	0.045	71	—
3	16.1 ± 0.19	26.5 ± 0.31	0.61	16.6	19.2	37	12	19	6	1.01	0.035	81½	—
4	18.2 ± 0.21	26.9 ± 0.34	0.68	24.4	34.6	36	12	20	4	1.73	0.065	79½	Mother-tree
5	16.3 ± 0.15	27.3 ± 0.34	0.60	23.1	28.8	38	13	23	2	1.25	0.056	66½	—
6	17.3 ± 0.22	26.4 ± 0.42	0.66	26.5	32.5	31	12	17	2	1.91	0.079	73	—
7	17.4 ± 0.17	24.8 ± 0.38	0.70	22.9	34.9	23	9	12	2	2.91	0.140	62½	—
8	17.5 ± 0.23	25.7 ± 0.38	0.68	21.9	32.0	23	10	11	2	2.91	0.127	68½	—
9	17.0 ± 0.19	25.3 ± 0.35	0.67	14.7	20.0	28	11	13	4	1.54	0.070	66	—
10	17.7 ± 0.20	25.6 ± 0.27	0.69	24.1	32.7	24	10	11	3	2.98	0.144	62	—
11	17.4 ± 0.24	25.1 ± 0.31	0.69	36.6	49.3	33	9	21	3	2.35	0.085	83	—
14	17.8 ± 0.30	24.6 ± 0.28	0.72	5.4	6.0	24	10	12	2	0.50	0.036	41½	Mother-tree 292 Tapped 2 years only
8/6/1	17.6 ± 0.29	23.8 ± 0.20	0.74	9.1	12.2	24	7	14	3	0.87	0.031		
4	21.2 ± 0.28	27.0 ± 0.36	0.78	51.3	91.9	36	8	24	4	3.82	0.141		Mother-tree 317
6	17.2 ± 0.34	24.7 ± 0.26	0.70	12.2	19.7	20	88	10	2	1.97	0.095		

Table V

Diameter of the latex tubes and yield of Kampong trees.

Position in Soengei Pantjoer block/row/ree 1	Diameter of the latex tubes in μ		Ratio leafstalk/bark 4	Production in grammes of dry rubber per tapping		Number of rings of latex tubes			Production 1928 of			Circumference at 1 m height in cm 13	Remarks
	leafstalk 2	bark 3		1926/28 5	1928 6	total 7	within 1.6 mm 8	productive 9	hard bark 10	productive ring 11	1 cm productive ring 12		
43/2/1	14.4±0.27	25.8±0.27	0.56	3.3	3.3	15	7	5	3	0.66	0.035	57½	Tapped 1 year only
2	15.8±0.26	25.6±0.23	0.62	2.1	2.1	12	7	2	2	1.05	0.056	56	Tapped 1 year only
3	18.2±0.31	21.9±0.23	0.83	6.8	8.8	18	5	11	2	0.80	0.029	84	—
4	15.7±0.23	22.8±0.24	0.69	5.5	7.0	24	10	12	2	0.58	0.029	60	—
5	14.5±0.25	22.2±0.25	0.65	5.0	5.2	15	5	8	2	0.65	0.026	76	—
6	19.1±0.31	26.0±0.33	0.73	4.7	7.7	19	9	8	2	0.96	0.044	66	—
7	17.2±0.28	22.6±0.24	0.76	6.5	8.0	18	7	9	2	0.88	0.040	66½	—
8	17.7±0.35	24.6±0.28	0.72	7.0	6.8	18	5	9	4	0.75	0.026	87½	—
9	17.0±0.30	25.0±0.25	0.68	5.3	5.3	21	7	12	2	0.44	0.017	76	Tapped 1 year only
10	16.2±0.28	24.7±0.23	0.66	7.2	9.2	26	11	10	5	0.92	0.031	88	—
11	14.9±0.26	23.6±0.25	0.63	5.1	7.4	15	5	8	2	0.92	0.041	66½	—
12	18.2±0.33	24.3±0.27	0.75	12.5	19.2	26	12	12	2	1.60	0.079	60½	—
13	16.7±0.24	24.2±0.21	0.69	4.4	3.6	15	4	7	4	0.51	0.021	73	—
14	17.4±0.27	25.4±0.25	0.68	2.3	3.3	16	5	9	2	0.36	0.018	61½	—

As appears from tables IV and V (column 4) the assumption is correct with certain limits. But all the same variation from 0·56 to 0·83, or 32·5%, in the ratio diameter of leafstalk tube 1 diameter of bark tube in table V is noteworthy, whilst table IV shows a more constant ration (variation 0·61 to 0·78). The average of all 29 relative figures is $0·689 \pm 0·010$; this is therefore the factor for an approximate calculation of the diameters in the leafstalk from those in the bark or vice versa.

Compiling correlation tables from the data in the tables IV, and V, a striking correlation between the diameter of the latex tubes and the yield is not found. Correlation table VI represents the measurements of leafstalks in correlation with the yield. The data concerning buddings from table III have also been used for the compilation of this table, using the yields of the third year of tapping, as with the examined seedlings. For clones 180, 183, 214 and 256, yield measurements not being available for the third tapping year, the yields are extrapolated. The seedlings are indicated by their position in Soengei Pantjoer (for mother-trees the selection number is also given in parenthesis), whilst the clone numbers are indicated by cl.

Correlation table VII gives the diameter of the bark tubes. Here again the correlation is bad. Comparison of correlation table VII with correlation table VIII, in which the number of rings of latex tubes has been compiled, is not in favour of the former. As it was the object of this investigation to find a better correlation for the identification of good yielders than the usual, unsatisfactory correlation between yield and number of latex tubes, it seemed only a loss of time to continue the measurements. Rather a better arrangement of the data gathered thus far should be attempted and the fundamental idea of Ashplant and the considerations set forth in section 2 should be probed for possible fundamental errors.

10. *Rings of productive tubes.*—First an attempt was made to calculate the yield per tapped ring of latex tubes, as done by Ashplant in his second correlation table.

Taking into consideration only the productive rings, *i.e.*, the rings which are actually opened by tapping and contain latex which can flow out, should result in a better correlation. Haigh has also drawn attention to the fact that the bark zone of $\pm 1·6$ mm. near the cambium is not touched by the tapping knife. But in the actually tapped bark there are also rings which do not yield since the contents are coagulated. Haigh tried to investigate this by means of a micro-chemical process, but this yielded peculiar results. Perhaps it would be better to ascertain this from physiological considerations. Bobiloff has already drawn attention to the fact that the tubes in the hard bark are in less favourable condition than those in the soft bark. According to Zimmermann and Arisz the latex tubes, when tapped must absorb water. This water is supplied from the wood through the medullary rays. It is evident, therefore, that a tube which is separated from the soft bark by a closed sclerenchymatous ring cannot function normally since the water supply is interrupted. In the same way rings, which are interrupted by sclerenchyma do not function well, since the change of turgor in the mantle of latex tubes, caused by the tapping cannot be evenly transmitted through the whole system of tubes. The latex flow from such tubes will therefore gradually decrease to nil; besides, it can be seen also when the tapping is very shallow, that the latex in the outer rings is coagulated.

In this treatise, therefore, as productive rings are considered those rings, which are situated between 1·6 mm. from the cambium and those which are interrupted or totally separated from the soft bark by sclerenchyma (see columns 7-10 in tables IV and V).

Table VI
 Correlation between yield (3rd year of tapping) and diameter of the latex tubes of the leafstalk.
 Correlation coefficient $+0.54 \pm 0.11$. Yield in grammes of dry rubber per tapping.

Diameter of the latex tubes of the leafstalk in μ	Correlation coefficient $+0.54 \pm 0.11$. Yield in grammes of dry rubber per tapping.												Total							
	0	5	10	15	20	25	30	35	40	45	50	55		60	65	70	75	80	85	90
14	43/2/1	43/2/5 43/2/11																		3
15	43/2/2	43/2/4																		2
16	43/2/13	43/2/10		8/12/3	8/12/1 cl. 49	8/12/5	cl. 50													7
17	43/2/14	8/12/14 43/2/7 43/2/8 43/2/9	8/6/1	8/6/6 cl. 35 cl. 80	8/12/9 cl. 33 cl. 36 cl. 152 cl. 163		8/12/6 8/12/7 8/12/8 8/12/10	8/12/11 (=292)												19
18	cl. 180	43/2/3		8/12/2 43/2/12	cl. 71	cl. 214	8/12/4 (=293) cl. 183													8
9		43/2/6					cl. 256													2
20																				0
21																			8/6/4 (=317)	1
	5	10	1	6	8	2	8	0	0	1	0	0	0	0	0	0	0	0	1	42

Diameter of the latex tubes of the leafstalk in μ

Table VII

Correlation between yield (3rd year of tapping) and diameter of the latex tubes of the bark. Correlation coefficient +0.49 ± 0.14. Yield in grammes of dry rubber per tapping.

	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	
21		43/2/3																		
22		43/2/4 43/2/5 43/2/7																		
23		43/12/11	8/6/1																	
24	43/2/13	8/12/14 43/2/8 43/2/10		8/6/6 43/2/12			8/12/7													
25	43/2/1 43/2/3	43/2/9			8/12/9					8/12/8 (=292)										
26		43/2/6		8/12/2 8/12/3	8/12/1															
27																			8/6/4 (=317)	
	4	10	1	4	2	1	5	0	0	1	0	0	0	0	0	0	0	0	1	29

Diameter of the latex tubes of the bark in μ

The correlation between the diameters of the latex tubes should be improved by the calculation of the yield per productive ring since the dynamical considerations of section 2 do not apply to the other rings. Further the influence of the differences in the circumference can be eliminated by dividing the yields per productive ring, corresponding with the length of the tapping cut, by $1/3$ of the circumference; in this way the yield per 1 cm. of productive ring is obtained. In this manner the factors (n') and (o) are eliminated from equation (3) and consequently the influence of the diameter, which occurs in the fourth power, should be increasingly manifested.

The correlation tables IX and X contain the data calculated in this way. The measures taken have not improved the correlation, on the contrary; as more changeable factors are eliminated, the correlation becomes worse. This appears from tables VII, IX and X and the following table in which, besides the correlations of the tables VI-X, the correlation coefficients between the diameters of the tubes of the leafstalk and the converted production figures have also been inserted.

In connection with the large standard deviations there is no real difference between these diameter correlation coefficients. Nevertheless it is noteworthy that they become systematically smaller and the standard deviations increase proportionally when trying to improve the correlation by calculation of the yield per productive ring or per 1 cm. productive ring. This in contradiction to what might have been expected, and also with Ashplant's results, who, when calculating the yield per productive ring according to his method, finds a considerably better correlation (+0.83) than for the total yield (+0.76).

Table IX

Correlation between the yield of one productive ring and the diameter of the latex tubes of the bark. Correlation coefficient $+0.41 \pm 0.15$. Yield (grammes of dry rubber per tapping) per productive ring.

Diameter of the latex tubes of the bark in μ	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	
21				43/2/3																
22		43/2/4	43/2/5	32/2/7																
23				8/6/1 +3/2/11																1
24		8/12/14 43/2/13	43/2/8	43/2/10				43/2/12	8/6/6					8/12/7						3
25	43/2/14	43/2/9	43/2/1		43/2/2		8/12/9				8/12/11 (=292)			8/12/8 8/12/10						8
26				43/2/6	8/12/2 8/12/3	8/12/1		8/12/4 (=293)	8/12/6											6
27						8/12/5														8/6/4 (=317)
	1	4	3	6	3	2	1	2	2	0	1	0	0	3	0	0	0	0	1	29

Diameter of the latex tubes of the bark in μ

Table X

Correlation between the yield per 1 cm. productive ring and the diameter of the latex tubes of the bark. Correlation coefficient +0.36 ± 0.16. Yield (grammes of dry rubber per tapping) per 1 cm. productive ring.

	0.014	0.021	0.028	0.035	0.042	0.049	0.056	0.063	0.070	0.077	0.084	0.091	0.098	0.105	0.112	0.119	0.126	0.133	0.140		
21			43/2/3																	1	
22		43/2/5	43/2/4	43/2/7																	3
23			8/6/1	43/2/11																	2
24		43/2/8	43/2/10	8/12/14						43/2/12		8/6/6									7
25	43/2/9 43/2/14			43/2/1			43/2/2		8/12/9		8/12/11 (=292)				8/12/8						8
26			8/12/3	8/12/2 43/2/6	8/12/1		8/12/4 (=293)			8/12/6											8
27							8/12/5														2
	2	3	4	5	2	1	2	1	1	2	1	1	0	0	0	0	1	0	3	0	29

Diameter of the latex tubes of the bark in μ

Correlation between	Production 1928	Production 1928 of one productive ring	Production 1928 of 1 cm Productive ring
Diameter of the latex tubes of the leafstalk	$+0.50 \pm 0.11$	$+0.50 \pm 0.14$	$+0.44 \pm 0.15$
Diameter of the latex tubes of the bark	$\times 0.47 \pm 0.14$	$+0.41 \pm 0.15$	$+0.36 \pm 0.16$
Number of productive rings of latex tubes	$+0.75 \pm 0.08$	—	—

On the other hand it is found, in agreement with Ashplant, that the leafstalk gives a better correlation than the bark. This is rather strange, since the latex must flow through the tubes of the bark and not through the leafstalk. If other investigators also find a better correlation for the leafstalk, then Ashplant has indeed found a very remarkable relation between anatomy and yield, which will not be easily explainable. Ashplant considers the bark unsuitable for measurements since he could not find a constant diameter in the bark. By measuring exclusively in the productive zone constant averages were obtainable in this investigation; the standard deviations only slightly exceed those of the leafstalk (the average of all standard deviations of the seedlings amounts to 0.25μ for the leafstalk and to 0.29μ for the bark). On the other hand the variations of the averages of the latex tubes in the bark, taking into consideration their larger diameter, is relatively smaller as compared with the tubes of the leafstalk. It is possible that this or unknown errors in measuring, or both, prejudices the correlation of the bark tubes as compared to the leafstalk tubes.

The correlation coefficients derived from the examined material are all so small that no value can be set upon them. Especially they do not bear comparison with the correlation coefficient 0.75 between yield and number of rings of latex tubes. Since only productive rings have been considered this coefficient should not be directly compared with that of Bobilioff ($+0.55 \pm 0.05$). Besides the difference in the numbers of examined trees is much too large (29 as against 491).

Little as the coefficients of the diameter imply it is still instructive to make a closer study of the tables. It appears from tables VI and VII that the trees with smallest tubes yield poorly and those with the widest tubes yield very well. But this hypothesis is not reversible, since there are many trees with large tubes which yield indifferently or even poorly; they are to be found in the table in the lower left square.

The possibility exists that the correlation is not a proportional one, the data not being arranged along a straight line but in a triangle; in connection with the paucity of data this possibility should be expressed with the necessary reserve. If curves are constructed from the correlation tables the diameter groups form a symmetric curve; the yield groups however form a very symmetric curve with a considerable accumulation at the left side.

It follows from the tables, that there are trees which yield less than might be expected from the diameter of their tubes, whilst on the other hand there are no trees which yield above their diameter. It can be stated therefore, that a small diameter of the tubes limits the yield of rubber, but that a large diameter gives no certainty that the tree will be a good yielder. (Something of the same kind applies, to a lesser degree, to the number of rings of latex tubes; see table VIII).

A large diameter of the latex tubes is an essential condition for, but unfortunately no proof of a high-yielding tree.