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Some Structural Factors Affecting the Productivity of **Hevea brasiliensis.** *III. Correlation Studies between Structural Factors and Plugging*

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The variations in bark structural properties and flow properties of control and stimulated trees of five clones were examined and their interrelationships studied. This study aims to seek suitable parameters related to plugging so that the connection between yield and easily measurable structural parameters can be established.

Girth, bark thickness, tapping cut length, latex vessel ring number and vessel volume in the tapping panel were all interrelated and these properties were in turn related to the total yield. In the stimulated trees however, the latex vessel ring number was not related to the total yield. Girth, latex vessel ring number, density and size were also related to plugging, i.e. *to both the indices of plugging and micro-plugging. However, only a maximum of 22% of the variation was explainable. Its significance is discussed.*

Plugging of latex vessels at or near the surface of the tapping cut resulting in the restriction of latex flow was first demonstrated by Boatman[1] in his experiments on repeated reopening of the tapping cuts. This later led to the introduction of the concept of 'plugging index'[2] which is a measure of the rate of plugging, *i.e.* ratio of initial flow rate to that of total yield. Other ratios like the flow ratio[3] which was expected to give a measure of the drop in turgor pressure during the 1 h period after tapping was also attempted, to describe the kinetics of latex flow. The flow index and flow restriction index[4] were modifications of the plugging index where recording of total volume was avoided.

Many studies have been carried out in relation to the plugging index. Milford *et al.*[2] observed that these indices were clonal characteristics independent of age and relatively little affected by site factors. Narayanan and Abraham[5] however, found that plugging index differed significantly between clones at a site for a tapping system and between tapping systems within a clone at a site. Analysis of month-to-month variation of plugging indices also revealed seasonal trends[6].

Correlation studies of plugging index were mostly with yield and dry rubber content[2,7]. Other factors like the bark structure, response to stimulation and tapping systems, too, have been correlated with the plugging index. This paper examines the relationship of plugging to a number of bark structural properties. The samples taken were from mature trees and not from plants in the nursery as in the correlation studies of Narayanan *et al.*[8] Microplugging index, a measurement of plugging index on a microscale is also introduced in this paper, but the

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technique of microtapping from which the measurement was calculated was first mentioned by Wright in 1906[9]

EXPERIMENTAL

Trees in *Field 14D* of the RRIM Experiment Station were used in this study. Five clones were selected: RRIM 600, RRIM 501, Tjir 1, GT 1 and PB 86 and all trees were on the S/2.d/2 tapping system on *Panel B.* Eight trees per clone from each of control and stimulated treatments were sampled. Only one bark sampling was carried out as structural properties undergo growth changes and we did not want this to influence the matter under investigation. Furthermore, the workload involved was so heavy that repeated sampling was considered inadvisable. Stimulation with 10% ethephon was carried out at two-monthly intervals and at the time of sampling the trees had had two years of stimulation.

For the bark structural properties, bark samples were removed with a 2-cm punch at 1.5 m above the union at an untapped position in between the tapping cuts of the two opposite panels. The plugs were fixed in FAA, sectioned transversely by hand and stained with Sudan III. Latex vessel rings were counted with the aid of a light microscope and other bark cellular properties were determined from micrographs of sections fixed in osmium tetroxide, embedded in styrene methacrylate and stained with toluidine blue.

Individual tree yield, plugging index and microplugging index were determined fortnightly for the months of July, August and September of the sampling year (1977). Although the three months of yield sampling did not fully reflect the seasonal trend in yield over the year, it was thought that somewhat fixed properties such as structural properties should be compared with yield behaviour closer to the time of sampling than with a mean yield secured over a longer period of time in order to reflect the true relationship between structural properties and physiological properties involved in this study. *Plugging index (PI) is calculated as:*

$$\frac{\text{First 5 min flow rate (ml/min)}}{\text{Total latex yield}} \times 100$$

and microplugging index (MPI) as:

$$\frac{\text{First minute yield}}{\text{Total latex yield}} \times 100$$

Where the yield used in calculating the plugging index was obtained by the ordinary S/2.d/2 tapping system, that used for the microplugging index[10] was obtained by microtapping, *i.e.* the incision method using a hypodermic needle attached to a capillary tube with an open end. The incision was however, made at 2 m height above the tapping panel in the virgin bark. Data obtained were statistically analysed. Below are the complete list of the properties examined:

- Gross structural properties involving bark:
  - bole height as measured from union to the level of first branching
  - girth, *i.e.* circumference at 152 cm from union
  - tapping cut length
  - bark thickness as measured from samples of bark
- Basic bark cellular properties as determined from a constant selected area of 30 000 sq mm of print at magnification of 500 × *i.e.* 120 000 μm^2 of original section.

cell number per unit area of 120 000 μm^2

cell size (mean from selected area)

sieve tube size (mean from selected area)

- Latex vessel properties:

total ring number

radius) mean number based on
density) the latex vessels present within the 120 000 μm^2
size) (in selected area)

volume *i.e.* based on the total ring number present × size × bole height × girth

volume/specific area (*i.e.* volume of the first six rows of latex vessels).

volume of the tapping panel

- Latex flow properties:

yield (ml per tapping)

plugging index

microplugging index

RESULTS AND DISCUSSION

Variations in Bark Structural Properties

Table 1 gives the analysis of variance of the gross structural properties involving the bark. The bole height was not significantly different between clones and treatments. The girth, cut length and bark thickness showed highly significant differences between clones; treatment differences were however, not significant as expected.

The analysis of variance of the basic bark cellular properties is shown in *Table 2*. The cell number and its cross-sectional area (cell size) in the different clones were significant at 5% level. Stimulation showed no significant influence on these properties. However, the clonal and treatment differences of the sieve tube size were significant.

Of the latex vessel properties all except latex vessel volume and volume per specific area showed highly significant clonal differences *(Table 3)*. Treatment differences were highly significant for the latex vessel volume and the latex vessel

TABLE 1. ANALYSIS OF VARIANCE OF BARK PHYSICAL PROPERTIES

Source of variation	d.f.	Mean squares			
		Bole height	Girth	Bark thickness	Cut length
Treatment (Control *vs* stimulated)	1	931.61	146.34	0.01	3.66
Clones	4	26 973.21	1 147.17***	10.55***	233.16***
Treatment × clones	4	3 589.89	38.76	0.19	3.53
Error	70	12 411.72	45.52	0.53	17.52
s.d.		111.41	6.75	0.73	4.19
Mean		403.29	81.52	7.32	42.16
c.v.		27.62	8.28	9.95	9.93

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$

TABLE 2. ANALYSIS OF VARIANCE OF BASIC BARK CELLULAR PROPERTIES

Source of variation	d.f.	Mean squares Cell number	Cell size	Sieve tube size
Treatment (Control *vs* stimulated)	1	2 500.00	3 816.15	95 481.00*
Clones	3	9 403.10*	7 760.50*	106 530.00**
Treatment X clones	3	3 253.21	4 884.90	15 425.67
Error	56	1 470.90	1 815.59	14 805.57
s.d.		38.35	42.61	121.68
Mean		334.09	365.15	978.75
c.v.		11.48	11.67	13.85

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$

volume per specific area (*i.e.* only the latex vessel volume of the first six rings). Out of the four clones studied, three showed reduction in the volume with stimulation but only PB 86 and RRIM 600 showed significant reduction *(Figure 1)*. The rest of the latex vessel properties except the ring number, showed treatment differences to be just significant at 5% level.

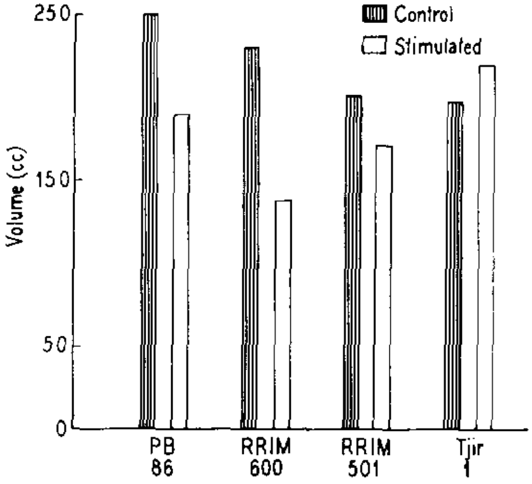

Figure 1. Latex vessel volume in specific area.

Variations in the Latex Flow Properties

The analysis of variance of the flow properties which includes the individual tree yield, plugging and microplugging indices is shown in *Table 4*. The yield did not seem to show any significant treatment differences contrary to what others have usually found. This is not surprising either, as results of Yip[11] obtained from trees in the same field have shown that only two of the clones, *i.e.* Tjir 1 and PB 86 demonstrated numerically positive yield responses during this particular period (but not significantly different yield levels); the yield data were however pooled for each clone. *Table 5* which shows individual tree means of the yield of the five clones also indicates similar numerically positive response with stimulation in these two clones. Therefore, it is due to the lack of response of the trees themselves during the period of study that treatment differences were not significant.

TABLE 3. ANALYSIS OF VARIANCE OF LATEX VESSEL PROPERTIES

Source of variation	d.f.	Mean squares L.V. ring no.	d.f.	L.V. radius	L.V. density	L.V. cross-sectional area	L.V. volume	L.V. volume/ specific area	L.V. volume in tapping panel
Treatment (Control *vs* stimulated)	1	12.80	1	3.61**	56.81*	14 074.83*	580 987.00**	35 161.91***	12 656*
Clones	4	446.26***	3	4.46**	255.00***	19 948.80**	232 881.75	5 011.51	14 793***
Treatment × clones	4	26.80	3	3.19**	18.20	13 429.16*	139 338.69	10 086.90*	4 116$^{P < 0.1}$
Error	70	20.60	56	0.49	13.30	2 204.27	106 943.70	3 301.20	1 825
s.d.		4.54		0.70	3.65	46.95	327.02	57.46	42.72
Mean		29.30		10.50	29.15	352.32	982.83	201.16	185.53
c.v.		15.49		6.67	12.51	13.33	33.27	28.56	23.03

*** $P < 0.001$
** $P < 0.01$
* $P < 0.05$
L.V. = Latex vessel

TABLE 4. ANALYSIS OF VARIANCE OF THE FLOW PROPERTIES

Source of variation	d.f.	Mean squares Yield	Plugging index	Micro plugging index
Treatment (Control *vs* stimulated)	1	20.00	36.26***	0.36
Clones	4	21 460.20*	12.84***	211.49***
Treatment *vs* clones	4	3 219.41	2.06	3.11
Error	70	4 061.28	0.52	8.24
s.d.		63.73	0.72	2.87
Mean		157.52	3.03	12.08
c.v.		40.46	23.79	23.75

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$

TABLE 5. MEANS OF YIELD, PLUGGING AND MICROPLUGGING INDICES OF THE FIVE CLONES FOR THE MONTHS OF JULY, AUGUST AND SEPTEMBER 1977

Clone	Yield (ml/tappings)		Plugging index		Microplugging index	
	Control	Stimulated	Control	Stimulated	Control	Stimulated
RRIM 600	234.75	191.88	3.14	2.42	11.01	12.62
Tjir 1	161.50	179.38	5.65	3.25	17.99	18.00
RRIM 501	151.38	150.63	3.02	2.15	10.07	9.41
GT 1	139.00	128.75	2.58	1.60	8.77	8.37
PB 86	103.50	134.50	4.13	2.36	12.24	12.34
S.E. (±)	22.53		0.25		1.01	
L.S.D.	63.63		0.72		2.87	

The plugging index as expected[7] showed highly significant clonal and treatment differences: stimulated trees having lower plugging index than the control *(Table 5)*. If the major effect of yield stimulant is to prolong the latex flow by delaying the onset of latex vessel plugging and at the same time reducing the plugging index[1], this fact then does not explain the insignificant yield differences obtained between control and stimulated trees. It has however been suggested by Yip and Gomez[12] that other factors besides latex vessel plugging may be involved in the yield response. It should also be noted that the two clones, Tjir 1 and PB 86 which showed numerically positive response to stimulation have comparatively rather higher plugging index in the control trees. In the stimulated trees, however, their plugging index were markedly lowered in comparison to the rest of the clones, a decrease of about 2.40 and 1.77 in Tjir 1 and PB 86 respectively indicating that the responding clones had a greater difference in plugging index between control and stimulated trees.

The microplugging index which is a useful measure of plugging especially where the latex flow is only for a short duration was also analysed by the analysis of variance method *(Table 4)*. The variations in the plugging index and microplugging index were almost similar: about 23.8%. Microplugging index however, showed highly significant clonal differences, but not treatment differences as observed for plugging index. From the table of means *(Table 5)* only RRIM 501 and GT 1 showed lower microplugging index in the stimulated trees than in the control: but then these values were not significantly different. The method of microplugging index measurement involves an unstimulated zone of the trunk interrupted by an island of renewing bark and this may be the reason why the treatment differences were not evident as stimulation applied on the cut may not have wide range effects on the whole bole of the tree.

Interrelationship between Bark Structural Properties

The correlation matrix of the bark structural properties is shown in *Table 6*. The bole height did not seem to be significantly related to most of the other structural properties in the control trees except for latex vessel per specific area. In the stimulated trees however, the bole height was to a lesser extent negatively related to the bark thickness and latex vessel volume.

The girth was highly correlated to the cut length, bark thickness, and latex vessel volume in the tapping panel of both control and stimulated trees. These results are according to normal expectations. Its correlation to the latex vessel ring number in the control trees was also highly significant and surprisingly the trees of the stimulated group showed a poor correlation.

The cut length showed a high correlation to the bark thickness in both the control and stimulated trees. The latex vessel ring number and vessel volume in the tapping panel were also highly correlated to the cut length in the control trees while the correlations in the stimulated trees were just significant at the 5% level. The cut length also showed a negative relationship of a lower order to the latex vessel density, in both control and stimulated trees.

The bark thickness was positively related to the latex vessel ring number and the vessel volume in the tapping panel of both the control and stimulated groups of trees. Its correlation to the cell number was significant only in the control trees. The cell number in turn was positively correlated to the latex vessel density in the control trees only. It was however, negatively correlated to the latex vessel cross-sectional area (size); more so in the control than in the stimulated trees, *i.e.* the more the cell number of the contiguous parenchyma cells, the smaller was the size of the latex vessels. The positive correlation of latex vessel ring number to the cell number was only just significant. The sieve tube size on the other hand was not significantly related to any of the bark structural properties.

In the latex vessel properties, the ring number was significantly related to the girth, cut length and latex vessel volume

TABLE 6. CORRELATION MATRIX OF THE BARK STRUCTURAL PROPERTIES

Property	Bole height		Girth		Cut length		Bark thickness	
	C	S	C	S	C	S	C	S
Bole height								
Girth	–0.273$^{P<0.1}$	–0.189						
Cut length	–0.254	–0.099	0.893***	0.923***				
Bark thickness	–0.250	–0.382*	0.656***	0.694***	0.709***	0.639***		
Cell number	–0.024	0.069	0.0803	–0.137	0.213	–0.109	0.414**	0.148
Sieve tube size	–0.026	0.188	–0.073	0.082	–0.081	0.078	–0.252	–0.169
L.V. ring number	–0.025	–0.102	0.503***	0.347*	0.640***	0.296$^{P<0.1}$	0.780***	0.586***
L.V. density	0.089	–0.099	–0.340*	–0.393*	–0.272$^{P<0.1}$	–0.381*	–0.095	–0.132
L.V. cross sect. area	–0.082	–0.159	0.033	0.188	–0.133	0.060	–0.240	–0.028
L.V. in tapping panel	–0.086	–0.402*	0.615***	0.508***	0.673***	0.441*	0.720***	0.767***
L.V. specific area	0.535**	0.4915**	0.073	0.169	0.077	0.128	–0.107	–0.076

TABLE 6. CORRELATION MATRIX OF THE BARK STRUCTURAL PROPERTIES (contd.)

Property	Cell number C	Cell number S	Sieve tube size C	Sieve tube size S	L.V. ring number C	L.V. ring number S	L.V. density C	L.V. density S	L.V. cross-sectional area C	L.V. cross-sectional area S
Sieve tube size	−0.300 $^{P<0.1}$	−0.222								
L.V. ring number	0.329*	0.425*	−0.047	−0.218						
L.V. density	0.431**	0.202	−0.081	0.143	−0.015	−0.221				
L.V. cross sect. area	−0.471**	−0.415*	0.131	0.132	−0.388*	−0.648***	−0.570***	−0.099		
L.V. in tapping panel	0.252	0.161 $^{P<0.1}$	−0.25	0.067	0.836***	0.346 $^{P<0.1}$	0.113	0.275	0.115	0.058
L.V. specific area	-0.016	−0.156	0.157	0.343*	0.067	−0.521**	0.048	0.226	0.322 $^{P<0.1}$	0.605***

*** $P < 0.001$
** $P < 0.01$
* $P < 0.05$
C = Control
S = Stimulated

in the tapping panel in control trees only; in stimulated trees the latex vessel size was negatively related to the ring number. Bark thickness was also related to the vessel ring number, in both the control and stimulated trees. The density of the latex vessels was significantly related to the size; the higher the density of the latex vessels, the smaller was the size, but only in the control trees.

Relationship between Initial Yield and Bark Structural Properties and Other Flow Properties

The correlation was based on the first 5-min yield and the matrix is shown in *Table 7.* Of the bark structural properties, girth and cut length were positively related to the initial yield in both control and stimulated trees. Other correlations like the latex vessel volume in the tapping panel and latex vessel density were significant only to a lesser extent.

The high correlation of the initial yield to the total yield was as expected and a similar relationship has been shown elsewhere[7]. Both the control and stimulated trees showed positive correlation. The plugging and microplugging indices too were positively related to the initial yield.

Relationship between Total Yield and Bark Structural Properties and Other Flow Properties

The total yield data used in this correlation study was based on the three-month collection which was made a few months after the bark samplings. The girth and cut length showed significant relationships to the total yield of both control and stimulated trees. Cut length has been shown before to be related to the total yield especially by Narayanan and Abraham[5]. The bark thickness, latex vessel ring number and latex vessel volume in the tapping panel, on the other hand, were related to the total yield only in the control trees. Narayanan *et al.*[13] have also shown that within clones, girth, latex vessel ring number and bark thickness were related to the total yield. The absence of correlation between yield and sieve tube diameter as seen here was also demonstrated by Narayanan *et al.*[8] This is however, contrary to the results of Fernando and Tambiah[14] and also the hypothesis of Gunnery[15] who first proposed the relationship.

The correlation matrix *(Table 7)* also showed that both plugging and microplugging indices were not significantly related to the total yield. This is rather unexpected and may be attributed either to the peculiar behaviour of the trees during the three-month period (*i.e.* July, August and September) as mentioned earlier in the discussion on the analysis of variance or due to the limitations of the data gathered. However, correlation of the data obtained for the whole year, 1977 *(Table 8)* showed significant negative relationship, as expected, both in control and stimulated trees. Therefore, both the plugging and microplugging indices did not have any influence on the total yield for this particular three-month period. In the case of the plugging index even though the plugging index was reduced on stimulation, the total yield and plugging index were not correlated. Pooling of the data of the five clones may also have contributed to the insignificant relationship.

Relationship of Plugging and Microplugging Indices to the Bark Structural Properties

Only the control trees showed some significant relationship between plugging and structural factors. The girth and latex vessel size showed positive correlation

TABLE 7. CORRELATION MATRIX OF THE FLOW AND BARK STRUCTURAL PROPERTIES

Property	Initial yield		Total yield		Plugging index		Micro plugging index	
	C	S	C	S	C	S	C	S
Bole height	–0.158	–0.068	0.023	–0.058	–0.254	–0.018	–0.167	–0.177
Girth	0.704***	0.724***	0.564***	0.669***	0.337*	0.205	0.464**	0.299$^{P<0.1}$
Cut length	0.590***	0.657***	0.544***	0.640***	0.160	0.150	0.260	0.289$^{P<0.1}$
Bark thickness	0.290$^{P<0.1}$	0.325*	0.521***	0.388*	–0.104	0.043	–0.025	0.022
Cell number	–0.118	–0.136	–0.001	–0.047	–0.171	–0.002	–0.229	–0.341$^{P<0.1}$
Sieve tube size	0.063	0.276	–0.105	0.223	0.254	–0.021	0.118	0.165
L.V. ring number	0.245	–0.005	0.627***	0.206	–0.321*	–0.034	–0.257	–0.128
L.V. density	–0.395*	–0.190	–0.243	–0.190	–0.408**	–0.086	–0.388*	–0.165
L.V. cross-sect. area	0.252	0.417*	–0.038	0.071	0.389*	0.250	0.332*	0.265
L.V. volume in the tapping panel	0.418**	0.372*	0.616**	0.357*	–0.182	–0.057	–0.080	–0.101
L.V. volume/specific area	0.162	0.381*	0.131	0.125	0.003	0.171	0.049	0.001
Initial yield	–	–						
Total yield	0.541***	0.814***		–	–			
Plugging index	0.565***	0.388*	–0.235	–0.114	–			
Micro plugging index	0.662***	0.392*	–0.052	0.027	0.826***	0.528***		

*** P < 0.001
** P < 0.01
* P < 0.05

C = Control
S = Stimulated
L.V. = Latex vessel

TABLE 8. CORRELATION BETWEEN TOTAL YIELD AND PLUGGING INDEX OF FIVE CLONES, 1977[a].

Clone	Control	Stimulated
Within clone		
Tjir 1	−0.821***	−0.610***
RRIM 600	−0.756***	−0.620***
RRIM 501	−0.510***	−0.418***
GT 1	−0.640***	−0.223**
PB 86	−0.584***	−0.582***
Between clones	−0.520***	−0.355***

*** $P < 0.001$
** $P < 0.01$
* $P < 0.05$

[a]Extracted from results of Yip[11]

with plugging index and microplugging index but these were only significant at the 5% level. Plugging index was also shown to be negatively related to the latex vessel density and ring number of which only the former was negatively related to microplugging index.

A maximum of 22% of the variation in microplugging index was explained by the linear regression of microplugging index on girth. Though the correlation is significant, such a relationship could not effectively be used as a reliable single character to estimate plugging as the precision of such an estimate would be low. Since this paper did not examine multiple regression and other relationships involving several dependent variables, it cannot be said that such relationships involving several bark structural factors could not be used to estimate plugging.

CONCLUSION

The study shows that most of the bark structural properties examined with the exception of the bole height, latex vessel volume, vessel volume per specific area and the flow properties were clonal characteristics. Stimulation seems not to have any significant effect on the physical properties and nearly all the bark cellular properties (except sieve tube size which appeared to have been reduced). Latex vessel ring number was not affected but all the other vessel properties were affected by stimulation. The most significant effect was on the latex vessel volume per specific area (*i.e.* the first six rows of the latex vessel) where two out of the four clones examined showed a significant reduction on stimulation.

Being in the second year of continuous stimulation these groups of trees can be expected to show some abnormal results in their flow properties due to partial exhaustion of the trees. The lack of response of the trees in itself particularly during the three-month duration of study may have been the cause of the insignificant effects of stimulation seen on the total yield during this period. In the same way, the insignificant differences between treatments obtained for microplugging index can be explained; on the basis of location of microplugging index measurement.

Of the many bark structural properties considered, girth, bark thickness, cut length, latex vessel ring number and vessel volume in the tapping panel showed interrelationships with each other especially in the control trees. These were also the properties that were related to the total yield (except for the latex vessel ring number which was unrelated in the stimulated trees).

These simple correlations which were computed between clones also showed that four properties, *i.e.* girth, latex vessel ring number, density and size were correlated to plugging. The properties in the stimulated trees were however not related to plugging due to reasons given earlier. A maximum of 22% of the variation was only explainable in the best correlation obtained between plugging and the various properties studied indicating that each one was unreliable as a single character to estimate the value of a clone in its early stages of growth.

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REFERENCES

1. BOATMAN, S.G. (1966) Preliminary Studies on the Promotion of Latex Flow by Plant Growth Regulators. *J. Rubb. Res. Inst. Malaysia,* **19**(5), 243.

2. MILFORD, G.F.J., PAARDEKOOPER, E.C. AND HO CHAI YEE (1968) Latex Vessel Plugging: Its Importance to Yield and Clonal Behaviour. *J. Rubb. Res. Inst. Malaya,* **21**(3), 274.

3. RUBBER RESEARCH INSTITUTE OF MALAYSIA (1977) *Rep. Rubb. Res. Inst. Malaysia 1976,* 74.

4. SETHURAJ, M.R., SUBRONTO, SULOCHANAMMA, S. AND SUBBARAYALU, G. (1978) Two Indices to Quantify Latex Flow Characteristics in *Hevea brasiliensis. Indian J. Agric. Sci.,* **48**(9), 521.

5. NARAYANAN, R. AND ABRAHAM, P.D. (1976) Latex Vessel Plugging Indices and Their Variations for Clones, Sites and Tapping Systems. *J. Rubb. Res. Inst. Malaya,* **24**(5), 248.

6. RUBBER RESEARCH INSTITUTE OF MALAYSIA (1979) *Rep. Rubb. Res. Inst. Malaysia 1978,* 65.

7. PAARDEKOOPER, E.C. AND SANIT SAMOSORN (1968) Clonal Variation in Latex Flow Pattern. *J. Rubb. Res. Inst. Malaya,* **21**(3), 264.

8. NARAYANAN, R., HO, C.Y. AND CHEN, K.T. (1974) Clonal Nursery Studies in *Hevea.* III. Correlations between Yield, Structural Characters, Latex Constituents and Plugging Index. *J. Rubb. Res. Inst. Malaysia,* **24**(1), 1.

9. WRIGHT, H. (1906) *Para Rubber,* p. 253. Maclaren and Sons Ltd.

10. RUBBER RESEARCH INSTITUTE OF MALAYSIA (1980) *Rep. Rubb. Res. Inst. Malaysia 1979,* 59.

11. YIP, E. (1981) Private communication. Rubber Research Institute of Malaysia.

12. YIP, E. AND GOMEZ, J.B. (1980) Factors Influencing the Colloidal Stability of Fresh Clonal *Hevea* Latices as Determined by the Aerosol OT Test. *J. Rubb. Res. Inst. Malaysia,* **28**(2), 86.

13. NARAYANAN, R., GOMEZ, J.B. AND CHEN, K.T. (1973) Some Structural Factors Affecting the Productivity of *Hevea brasiliensis.* II. Correlation Studies between Structural Factors and Yield. *J. Rubb. Res. Inst. Malaysia,* **23**(4), 285.

14. FERNANDO, D.M. AND TAMBIAH, M.S. (1970) Sieve Tube Diameters and Yields in *Hevea* species. A Preliminary Study. *Q.Jl. Rubb. Res. Inst. Ceylon,* **46**, 88.

15. GUNNERY, H. (1935) Yield Prediction in *Hevea.* A Study of Sieve Tube Structure in Relation to Latex Yield. *J. Rubb. Res. Inst. Malaya,* **6**, 8.