

STUDIES ON LATEX FLOW PATTERNS AND PLUGGING INDICES OF CLONES

BY

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INTRODUCTION

The pattern of the flow of latex on tapping has been a field of research that has been revived only recently, though important initial concepts were established two decades ago by Frey-Wyssling (1952), Riches & Gooding (1952), Gooding (1952 a, 1952 b).

When a rubber tree is tapped the flow begins to decline soon after tapping, and ceases completely after a time. The initial decrease in the rate of flow is rapid while the subsequent decrease is gradual. These two phases of flow are usually referred to as the exponential and the hyperbolic, respectively. The total flow is thus an integration of these two phases of flow.

Insight into the mechanism controlling flow is of paramount importance especially in the exploitation of *Hevea*. Boatman (1966), Buttery & Boatman (1967) observed that the decrease in the rate of flow is due to an obstruction to the flow commencing soon after tapping. This obstruction is located at or near the cut ends of vessels and is the result of vessels being plugged internally with coagulated rubber. The internal plug formation is probably a swift process, starting moments after tapping, and with time as more and more vessels become plugged, a gradual decrease in the flow rate results; the flow ultimately ceases when all the vessels are plugged.

Recent research on latex flow stems mainly from the observations of Buttery & Boatman (1967) and has advanced in two main lines. In one, physico-chemical explanations are sought on the mechanism controlling vessel plugging (Southorn, 1968 a; 1968 b; Southorn & Edwin, 1968; Southorn & Esah Yip 1968 a; 1968 b; Esah Yip & Southorn, 1968), and in the other, studies are pursued on clonal differences in plugging behaviour and latex flow pattern (Milford *et al.*, 1968; Paardekooper *et al.*, 1968; Sethuraj, 1968 a; 1968 b).

The rapidity of plug formation is an important physiological clonal characteristic which is probably genetically determined. In a clone where plugging is fast, the rate of latex flow declines sharply and stops completely in a relatively short period. In clones where plug formation is slower the flow rate decreases very gradually resulting in prolonged flow duration. In practice, we find a wide spectrum of clones varying from one extreme to the other in this respect. Studies on flow curves and plugging behaviour of clones prompted Paardekooper *et al.* (1968) and Milford *et al.* (1968) to evolve an important parameter, "the plugging index", which is a good measure of the rapidity of plugging in clones. The plugging index is defined as one hundred times the initial flow rate (in ml/min) for the first five or ten minutes after tapping upon the total volume (yield) of latex.

Plugging index is related to many other clonal characters. It is negatively correlated with yield and incidence of dryness (Brown Bast) in trees, and positively correlated with girth increment, DRC of latex and response to yield stimulation. It also determines the clonal response to particular tapping systems. Perhaps, the most important attribute of the concept of plugging index is the information it furnishes on exploitation, both in respect of tapping systems and chemical yield stimulation.

This paper embodies studies on (a) flow patterns and plugging indices of some of the more important clones and the relationship of these with the other important clonal characters, (b) plugging indices of clones as influenced by breeding and genetic selection.

MATERIALS AND METHODS

Flow patterns and plugging indices of clones; the relationship with yield, girth increment and DRC

The clones on test included RRIM 513, 701, 707, and PB 28/59 from Malaysia, IRCI 9 from Vietnam, TR 1548 from Indonesia, and recent RRIC selections such as RRIC 7, 36, 41, 45, 52, 100 and 101 (Tables 1a and 1b). They were available from the 1961 clone trial at Dartonfield and the 1962 clone trials at Kuruwita Substation. Recordings were done during the period August 1969 to January 1970 on six trees per clone randomly selected; a minimum of six recordings per clone were done spaced over the above period. In flow-curve studies, flow fractions of latex were measured after tapping for 5 and 10 min, then at 10-min intervals for 90 min, at 30-min intervals for the next 90 min, thereafter at 60-min intervals until flow ceased. The plugging index was always worked out on the initial flow rate calculated from the first 5-min flow fraction. All trees were tapped on the virgin bark, on the S/2, d/2, 100% intensity tapping system.

RESULTS AND DISCUSSION

The flow patterns (curves) of a few clones grouped in order of their plugging indices is shown in Fig. 1. The main feature observable here is that from group 1 to 4 there is generally an increase in the gradient of the flow curves, and hence, a concomitant decrease in the flow duration. The plugging index is directly related with the gradient of the flow curve and inversely with the flow duration.

Statistical analysis of the plugging index data showed a highly significant variation between clones. A high intra-class correlation coefficient (0.7506) was obtained which confirms that plugging index is highly characteristic of a clone. Marked day to day and tree to tree variations within clones were also observed but were comparatively less than inter-clonal differences.

It has already been reported by Milford *et al.* (1968) that considerable seasonal and agroclimatic variations in the plugging index of a clone are possible. In the wet districts of Ceylon it appears that the plugging index reaches a maximum after winter defoliation and declines gradually until the onset of next winter. The decline from about August to December is almost negligible so that plugging index during this period may be considered static disregarding the diurnal fluctuations. For comparison of clones, therefore, values obtained in this part of the year are probably preferable.

Tables 1a and 1b show the relationship between the plugging index and other related clonal characters such as flow duration, yield, girth increment and DRC of latex. As established by Milford *et al.* (1968) and Paardekooper *et al.* (1968) significant correlations between plugging index and these characters have been obtained (Table 1c.) These authors have discussed at length the correlations between plugging index and the other related clonal characteristics, and this need not, therefore, be dealt with again.

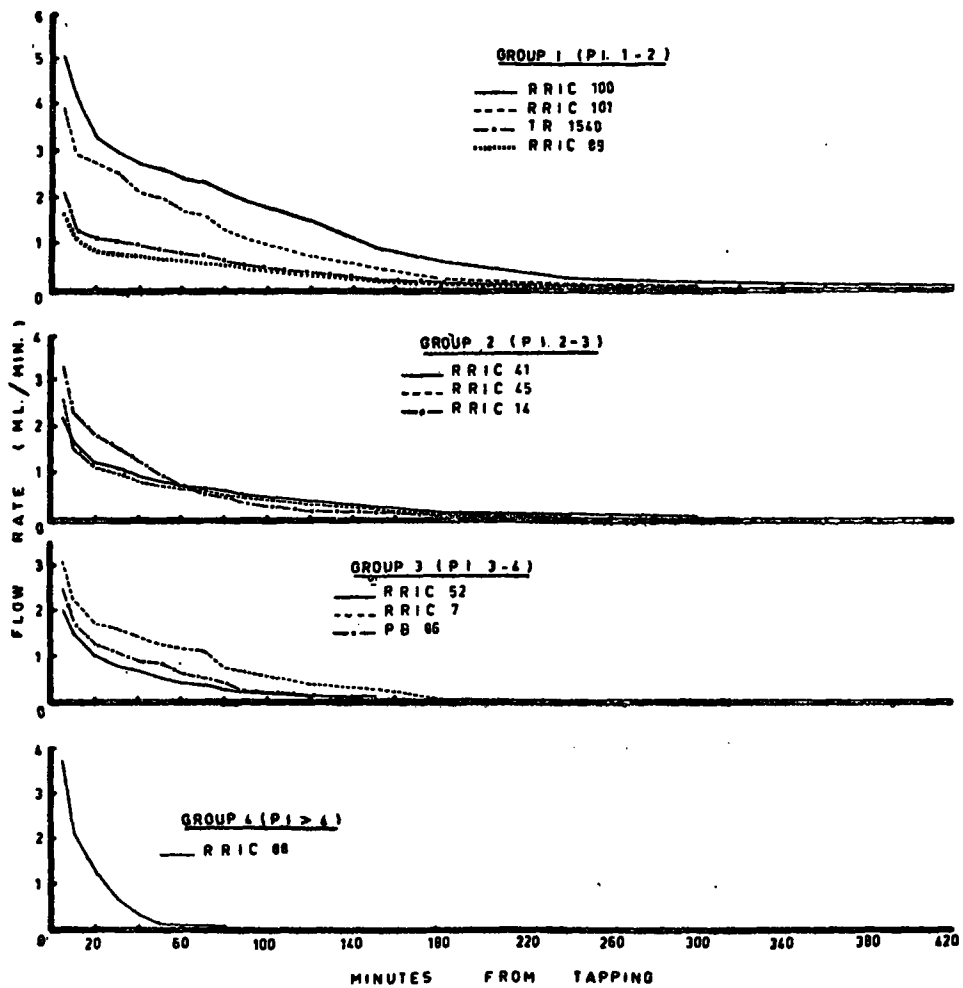


Fig. 1. Latex flow patterns of some *Hevea* clones

TABLE 1A

INTER-RELATIONSHIPS BETWEEN PLUGGING INDEX, FLOW DURATION,
YIELD, GIRTH INCREMENT AND DRC OF CLONES
(1962 Kuruwita Sub-station clone trial)

Clone	Plugging index	Flow duration (min)	Yield (g/tree/tapping)	Girth increment (cm)	DRC (%)
Group 1 (P.I 1-2)					
RRIC 100	1.40	390-420	63.7	2.7	26.2
RRIM 701	1.57	330-360	32.1	2.1	28.8
RRIC 37	1.68	270-300	27.5	2.8	29.2
RRIC 101	1.78	270-300	56.5	3.5	27.1
IRCI 9	1.89	270-300	38.5	3.7	28.4
TR 1548	1.92	270-300	25.0	3.6	30.6
Mean		300-330	40.6	3.1	28.4
Group 2 (P.I 2-3)					
RRIC 41	2.07	270-300	34.1	3.1	32.2
RRIC 36	2.14	270-300	35.3	2.9	28.6
RRIM 623	2.38	270-300	46.5	5.4	31.8
RRIC 45	2.45	270-300	36.9	2.8	29.8
RRIM 707	2.45	270-300	26.1	3.7	31.2
RRIC 14	2.87	180-210	31.4	4.5	38.0
Mean		255-285	35.1	3.7	31.9
Group 3 (P.I 3-4)					
RRIC 52	3.11	120-150	10.3	8.5	32.8

TABLE 1B

INTER-RELATIONSHIPS BETWEEN PLUGGING INDEX, FLOW DURATION,
YIELD, GIRTH INCREMENT AND DRC OF CLONES
(1961 Dartonfield clone trial)

Clone	Plugging index	Flow duration (min)	Yield (g/tree/tapping)	Girth increment (cm)	DRC %
Group 1 (P.I 1-2)					
RRIM 513	1.75	270-300	22.4	3.6	29.2
RRIC 89	1.78	270-300	30.8	4.1	30.5
PB 28/59	2.00	270-300	38.5	4.5	31.4
Mean		270-300	30.6	4.1	30.4
Group 2 (P.I 2-3)					
RRIC 45	2.45	210-240	18.2	3.6	29.2
Group 3 (P.I 3-4)					
PB 86	3.01	150-180	23.7	5.9	30.9
RRIC 7	3.38	150-180	26.6	4.3	30.0
RRIC 52	3.59	120-150	12.7	6.4	31.9
Mean		140-170	21.0	5.5	30.9
Group 4 (P.I 4)					
RRIC 88	6.68	60-90	16.2	6.0	35.2

TABLE 1C

INTER-RELATIONSHIPS BETWEEN PLUGGING INDEX, FLOW DURATION,
YIELD, GIRTH INCREMENT AND DRC
(1962 Kuruwita Sub-station clone trial)

Correlation coefficients

	Plugging index	Flow duration	Mean yield	Mean girth increment	DRC
Plugging index	1.0000	-0.8715*	-0.5716*	+0.7595*	+0.7577*
Flow duration		1.0000	+0.6970*	-0.7977*	-0.6808
Mean yield			1.0000	-0.4553	-0.3979
Mean girth increment				1.0000	+0.4996
DRC					1.0000

* Significant

In view of the fluctuations that occur, an absolute plugging index value for a clone is not quite precise. However a grouping of clones based primarily on their plugging indices combined with other characters should prove useful in many ways. A sample grouping of data is shown in Table 1a. The data available, so far, are inadequate for a comprehensive grouping of clones. Such a grouping is, however, not foolproof because clones at either end of a group could, at times, qualify for placement in the adjacent group.

It is seen (Tables 1a and 1b) that clones of groups 1 and 2 (the lower pluggers) are characterised by long flow duration, the flow decreasing relatively gradually with time. They are usually the higher yielders but with lower DRC. When in tapping their girth increment is relatively low. They are more susceptible to Brown Bast and are unlikely to respond to tapping cuts longer than half-spiral, intensities higher than 100% and chemical yield stimulation. On the other hand, clones of groups 3 and 4 (the higher pluggers) have a shorter flow duration, the flow decreasing more abruptly with time. They yield relatively less but have a higher DRC. Even when in tapping they are relatively more vigorous growers with higher girth increments. They are less susceptible to Brown Bast and are likely to respond better to increased cut-lengths, higher tapping intensities and yield stimulation.

The chief use of such a grouping would, perhaps, be in investigations on exploitation and yield stimulation because plugging index largely determines the clonal response to tapping systems and yield stimulation. A multiplicity of clones are grown commercially and more and more new clones are synthesised through intensive breeding programmes undertaken by our Institute and other similar institutes abroad.

It is thus impossible to test tapping systems and stimulants on each clone, and at the same time keep abreast in this regard with new clones put out frequently. A grouping of clones as suggested would overcome this difficulty to a large degree. A few representative clones from each group could then be tested out for different tapping systems and yield stimulants. Based on the findings the more appropriate tapping systems and yield stimulants may then be tested out clone-wise.

Influence of genetic selection on the plugging index: The plugging indices of several clones that are the parents of some clones from the 1961 Dartonfield clone trial and 1962 large scale Kuruwita Sub-station clone trial were recorded. The parental clones listed in Table 2 are from Hedigalla Sub-station, Nivitigalakele Sub-station or Dartonfield clone trials.

In order to obtain a fairly representative number of clonal plugging indices, that of the clones of the 1956 large scale clone trial at Hedigalla and the clones of the 1962 large scale clone trial at Nivitigalakele were also evaluated. In all, about 75 values were available for incorporation in the frequency distribution diagram (Fig. 2).

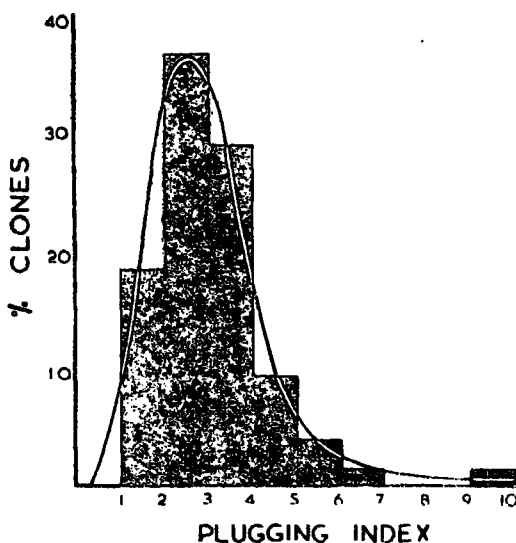


Fig. 2. Grouping of seventy five clones on the basis of plugging indices

Table 2 shows the plugging indices of some of the more recent local clones and of their parents. It indicates that in all of the hybrids the plugging index is strikingly lower than that of the parent clones. It should be mentioned that there was no bias in the selection of these hybrids and the respective parent clones and that these were the only ones available at the Institute's stations which satisfy the requirement. Fig. 2 shows the distribution of clones on the basis of their plugging indices. By far the majority of the clones therein are recent ones. The number of figures that has been utilized is inadequate to confidently refer to it as a frequency distribution diagram, but there is no doubt that it depicts satisfactorily the selection trend in clones in relation to the plugging index. The curve superimposed is very strongly skewed to the right indicating that selection has operated towards the low plugging character so that the majority of the presently grown clones are low pluggers.

TABLE 2
COMPARISON OF PLUGGING INDICES OF SOME RECENT CLONES WITH
THAT OF THE PARENTS

Hybrid	Parents
RRIC 36 (2.14)	PB 86 (3.01) × PR 107 (5.95)
RRIC 41 (2.07)	RRIC 8 (5.15) × Tjir 1 (9.03)
RRIC 45 (2.45)	RRIC 8 (5.15) × Tjir 1 (9.03)
RRIC 100 (1.40)	PB 86 (3.01) × RRIC 52 (3.59)
RRIC 101 (1.78)	Ch 26 (5.47) × RRIC 7 (3.38)
RRIC 102 (2.50)	RRIC 52 (3.59) × RRIC 7 (3.38)

As is obvious, the Institute's breeding programme is geared primarily towards the attainment of higher yields. Plugging index is highly inversely correlated with yield and incidence of dryness in trees. Thus selection for yield and consequently the low plugging character is likely to be associated with increased susceptibility to Brown Bast even when tapped on the half-spiral, alternate-daily system. This emphasises the fact that with the clones synthesized on the present breeding programme, aimed at high yields, the prospect of increasing the length of tapping cut or the relative intensity of tapping is diminishing. Accordingly, it appears that with our recent generation of high yielders such as RRIC 100, RRIC 101, RRIC 89 (with plugging indices of 1.40, 1.78 and 1.78 respectively) even the S/2, d/2, 100% system may be too intensive initially, and these clones could in the long run benefit from an initial (first five years) S/2, d/3, 67% tapping. However, selection has also operated towards greater vigour than the parents resulting in earlier opening of tapping cuts which offsets the lower intensity. This does not mean that none of the recent clones can be tapped on systems more intensive than S/2, d/2, 100% but that the majority of them are likely to react to increased cut-lengths and intensities higher than 100% with increased numbers of dry trees.

There is no doubt that selection of clones has proceeded in the correct direction, because for the rubber grower it would obviously be more economic to realise a certain yield from a high yielder tapped on a low intensity than from a low yielder tapped on a high intensity. Moreover, in general, the prospect of the hypothetical low yielder even when tapped on a high intensity yielding comparably with the high yielder tapped on a low intensity is also bleak.

The Institute, nevertheless, is also exploring the possibility of exploiting the high girth low yield selections (the high pluggers) on tapping intensities higher than 100%. An experiment has just been initiated at the Kuruwita Sub-station where nine-year old selections of this type have been moved up to 133% tapping intensity but several years' data would be required for conclusive evidence.

There is another important consideration. Though plugging index is inversely correlated with yield, clones differing considerably in their plugging index but comparable in yield are not uncommon. Then, a clone with the higher plugging index should obviously be preferred. One should thus hasten to incorporate such a genetic base in the breeding programme, for the advantages of this are manifold. This may alleviate to some degree the incidence of Brown Bast and late dripping characteristic of the high yielders without sacrificing the high yield character. The latex could be collected earlier after tapping thereby avoiding the risk of pre-coagulation in the field. The DRC could be higher. The growth vigour of trees and the response to increased tapping intensities could be better.

CONCLUSION

One of the main reasons that prompted the writers to present this paper today is to introduce to our local rubber planters this recent concept of plugging index. The plugging index is a clonal characteristic closely but inversely related with the yield. Thus as much as one speaks of the yield potential of a clone it would be useful for one to be accustomed to speak of its plugging index too. It is a simple criterion the assessment of which needs only a measuring cylinder and is well within the capability of the ordinary laymen. Nevertheless the information it furnishes in respect of exploitation and chemical yield stimulation cannot be overlooked. Many estates conduct tapping trials, by themselves, which no doubt is a good practice. In such trials, in deciding on the tapping systems it would be advisable to do so on the basis of the plugging indices of the clones under test. Awareness of the plugging behaviour of clones and the fact that this largely determines the response to tapping systems and yield stimulants would enable the enterprising planter to extract the maximum economic returns from his rubber trees.

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QUESTIONS AND ANSWERS

- Question: Is the plugging index lower in the double-four system when compared with the s/2, d/2 system? If so the duration of flow would be more resulting in an increase in yield. Would this be correct? (Anon).
- Answer: Yes, the plugging index is lower in the double-four system than in the s/2, d/2, 100% system. Your surmise is quite true, the yield is generally greater on the 2s/2, d/4, 100% system for the first two to three years, but then the yields drop, and that is why we do not recommend this system, particularly for young areas and for high-yielding clones. (Dr. O. S. Peries).
- Question: Will Mr. Waidyanatha kindly indicate the clones which may respond favourably to long tapping cuts on d/4 and full-spiral tapping in relation to plugging indices? (Anon).
- Answer: RRIC 52 responds well to full-spiral tapping, but here again it may be for a limited period, and our data on this problem are not complete. Therefore we are not recommending the system. (Dr. O. S. Peries).
- Question: Will the addition of an anticoagulant to Antimucin and thus on to the tapping panel affect (1) the bark, (2) reduce plug formation and thus increase the rate of flow and the yield? (Mr. Hapugoda).
- Answer: (1) Not that I can think of; without carrying out experiments, it is difficult to answer such a question — my answer would be a guess and yours should be as good as mine. Quite frankly, it is a crazy thing to do — like giving someone poison and an antidote in one dose. If you know that Antimucin reduces yields, why not use an alternative fungicide, without using an antidote?
(2) Not likely, as the mercury in Antimucin causes plug formation by denaturing proteins, and the normal anticoagulants now used in the rubber industry act in quite a different way. So it would not act. (Dr. O. S. Peries).
- Question: (a) Is there any variation in plugging index among plants in a single mono-clonal block of budded plants? (b) Is there any evidence to suggest that the rootstock may influence the plugging index? (Dr. Y. D. A. Senanayake).
- Answer: No, only very minor variations which could be expected in any normal population. (b) No, but sufficient work has not been done on this important aspect. We will be looking into this problem in due course. (Dr. O. S. Peries).
- Question: Selection has been for low pluggers in the RRIC breeding programme — Is this a good or bad thing? — please discuss. (Anon).
- Answer: It is a good thing and the correct breeding programme, as we have everything to gain from breeding low pluggers. However, there may be certain genetic factors in the high pluggers that we should not lose; therefore, there is a place for them in present day breeding programmes. (Dr. O. S. Peries).
- Question: Where the plugging index of a clone was low you suggested that a lower intensity tapping system should be adopted for the first four years. Where the plugging index is high as in RRIC 52, do you recommend a tapping system with a higher intensity from the first year of tapping, say 133%? (Mr. Percy de Silva).
- Answer: No, we do not recommend high intensity tapping of any present day clone, and even the double-four or the full-spiral until at least after the tenth year of tapping. RRIC 52 is a special clone. Our records and those from many commercial estates show that it is a late starter, and its yields compare favourably with those of other clones after about the fourth year of tapping (Dr. O. S. Peries).