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Latex Flow Studies VII. Influence of Length of Tapping Cut on Latex Flow Pattern

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The length of the tapping cut has a strong influence on the pattern of latex flow. Plugging is intense, turgor pressures remain high and yields per severed latex vessel are more for very short cuts. Theoretical and other implications of these findings are discussed.

Lutoid particles of latex, when damaged, release a serum (B-serum) which induces the formation of floccules capable of plugging a latex vessel (SOUTHORN AND EDWIN, 1968; SOUTHORN AND YIP, 1968). It has also been shown that the lutoids themselves are damaged when latex is forced through narrow-bore capillaries at sufficiently high pressure gradients, resulting in plugging of the capillary (YIP AND SOUTHORN, 1968). From these observations, SOUTHORN (1969) proposed that latex vessel plugging, and hence the pattern of latex flow, should be strongly influenced by the ability of the tree to sustain turgor pressures for appreciable periods in the region of the cut. For a short tapping cut, turgor pressures — and hence pressure gradients along the vessels — should be better maintained than would be the case with a long tapping cut. It was thought that, for this reason alone, vessel plugging should be most intense for very short cuts. Indirect supporting evidence came from the observation that full-spiral tapping generally results in longer flow times than does half spiral tapping and that trees under full spiral tapping respond less to yield stimulation than trees subjected to half-spiral tapping (MILFORD, PAARDEKOOPER AND HO, 1969). The present study was made to examine the actual flow pattern of *Hevea* from tapping cuts of different lengths to find out whether the predicted behaviour could be established by direct observation.

EXPERIMENTAL

In order to estimate differences in plugging, some quantitative indication of plugging is required. BOATMAN (1966) found that if a tree is tapped repeatedly at relatively short intervals, a resurgence of flow is obtained at each reopening indicating plugging. The 'stepped' flow curve so obtained is still the best available evidence for plugging. There are many ways of calculating an index of plugging intensity from the latex flow curves. MILFORD *et al.* (1969) and PAARDEKOOPER AND SAMOSORN (1969) have described a 'plugging index' calculated as

$$100 \times \frac{\text{Mean initial flow rate (ml/min)}}{\text{Total yield volume (ml)}}$$

The advantage of this method is that only two simple measurements are required per tree, so that it is practicable to make studies of numbers of trees and analyse the results statistically. The method has drawbacks, however, in that it involves a number of assumptions about the latex flow pattern which have only been checked for a few conventional tapping systems (mainly half spiral tapping). For the present study, the authors preferred to use an assessment of plugging intensity based directly on the stepped flow curve given by Boatman's technique, where the increase in flow rate resulting from re-tapping indicates unambiguously the extent to which flow had been impeded just before retapping. This type of experiment is too complex to be done on more than one or two trees at a time.

To give the results a numerical basis, the flow just before each tapping was related to that after tapping, such relationship being expressed as a percentage 'intensity of plugging' (IP). Thus, if *a* is the flow in the minute preceding

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tapping (g) and b is the flow in the minute after tapping (g), then IP = 100 × (b–a)/b. It follows that at the first tapping, where the vessels are completely blocked and there is no flow until the cut is made, this calculation would give a value of 100% plugging for IP. In a subsequent retapping, where the operation doubled the flow, the value of IP would be recorded as 50% plugging.

Changes in turgor pressure during the experiment and the varying numbers of latex vessel rings in different trees add complications which will be discussed later. Vessel counts were made by taking plugs of bark from the trees for sectioning and examination under the microscope. To reduce variability arising from depth of tapping, all cuts were made through to the cambium. The lengths of cuts studied ranged from pricks made with punches fabricated from hypodermic needles (microcuts) to tapping cuts extending for half the circumference at the tree (half spiral cut). Flow rates were in all cases estimated by collecting the latex into pre-weighed plastic tubes.

To establish the general pattern, preliminary work was done with two mature trees of clones RRIM 526 and Tjir 1 which had previously been in regular half spiral tapping. The trees were of different girths, a half spiral cut on the Tjir 1 tree measuring 610 mm, and on the RRIM 526 tree 330 mm. The results, comparing the flow at intervals from a half spiral cut to that from microcuts, are shown in *Table 1*. Only one cut was made for each experiment.

This experiment gave the following clear-cut indications:

(a) Although the larger cut yielded more latex, this was entirely due to the larger number of vessels severed. When expressed as yield per millimetre per vessel ring, the position was reversed; vessel for vessel, the yield was very much greater for the microcut than for the half spiral cut.

(b) Flow persisted longer for the half spiral cuts than for the microcuts, but this did not upset the above conclusion.

From these observations it was inferred that the vessels of the microcuts plugged more rapidly, but while they remained open the forces expelling latex from them (related to turgor pressure) were greater than for the vessels of the half spiral cuts.

TABLE 1. COMPARISON OF FLOW BEHAVIOUR BETWEEN HALF SPIRAL AND MICROCUTS ON TREES OF CLONES TJIR 1 AND RRIM 526

Details of flow	Clone: Tjir 1 (25)*		Tjir 1 (25)*		RRIM 526 (26)*	
Length of cut (mm)	1.0	610	1.5	610	1.0	330
Flow after tapping (g/min)						
over 1st minute	0.8	12.0	1.6	14.0	0.7	8.0
over 5th minute	0.1	4.0	0.1	4.0	0.3	3.0
over 10th minute	†	3.0	†	1.0	0.1	2.0
over 30th minute	–	0.6	–	0.1	–	0.4
Total yield of latex (g)	3	107	3	70	4	63
Yield/mm/vessel ring (mg)	120	7	85	5	134	7

†Flow less than 0.1 g/min.
*Number of vessel rings.

For the next series of experiments, a comparison of the 'repeated tapping' flow curves was made between trees of clones PR 107 and RRIM 501 for tapping cuts of different lengths. After initial tapping, the cuts were reopened at 20-minute intervals, the flow rate being followed throughout for a period of 100 minutes during which each tree was subjected to initial tapping plus four retappings. Two trees of each clone were used. In comparing a short cut with a longer one, there was a possibility that the position of the short cut might influence the result. In the case of trees of clone PR 107, this was checked for S 3/8 and S 1/8 cuts by repeat experiments making the shorter cuts along the upper and lower segments of the half spiral cuts previously tested. The results are given in *Tables 2* and *3*.

The results show that the intensity of plugging increases as the length of cut decreases. Clone RRIM 501 was included in these experiments because of its reputation for low plugging on half spiral tapping which is confirmed in these results. However, even the trees

TABLE 2. COMPARISON OF INTENSITY OF PLUGGING* SHOWN BY TWO TREES (A AND B) OF CLONE RRIM 501 WHEN REOPENED AT 20-MINUTE INTERVALS BY HALF SPIRAL AND ONE-INCH CUTS

Tree	Length of cut	Intensity of plugging (%) at each reopening after 20 minutes				Mean intensity of plugging (%) after 20 min
		1st	2nd	3rd	4th	
A	Half spiral	0	5.4	10.1	5.0	5.7
B	Half spiral	6.9	8.5	6.5	3.4	
A	One-inch	28.7	21.1	15.9	12.2	50.1
B	One-inch	56.9	98.5	88.7	79.2	

*At the initial tapping the trees would be 100% plugged.

of RRIM 501 showed very marked plugging after 20 minutes with cuts of only 1 inch length. The position of the short cut in relation to the

TABLE 3. COMPARISON OF INTENSITY OF PLUGGING* SHOWN BY TWO TREES (A AND B) OF CLONES PR 107 WHEN REOPENED AT 20-MINUTE INTERVALS BY CUTS OF DIFFERING LENGTHS

Tree	Length of cut	Intensity of plugging (%) at each reopening after 20 minutes				Mean intensity of plugging (%) after 20 minutes
		1st	2nd	3rd	4th	
A	Half spiral	7.1	19.9	28.3	34.7	20.2
B	Half spiral	10.0	25.4	13.2	22.8	
A upper	3/8 spiral	38.8	69.2	65.3	57.2	53.8
lower	,, ,,	16.5	53.5	47.6	49.9	
B upper	,, ,,	78.8	29.8	45.1	51.7	
lower	,, ,,	46.5	71.8	72.3	66.9	
A upper	1/8 spiral	73.0	82.8	87.6	61.7	74.9
,,		60.4	83.8	83.4	92.6	
lower		68.8	95.6	74.2	88.5	
,,		70.8	91.6	82.9	74.9	
B upper		64.8	63.5	70.7	61.6	
,,		74.1	94.0	80.8	73.5	
lower		74.3	73.2	64.6	71.4	
,,		65.9	59.2	66.9	65.3	
A upper	1-inch spiral	87.1	86.2	99.4	81.1	89.0
B ,,	,, ,,	83.8	93.7	98.4	91.6	

*At the initial tapping the trees would be 100% plugged.

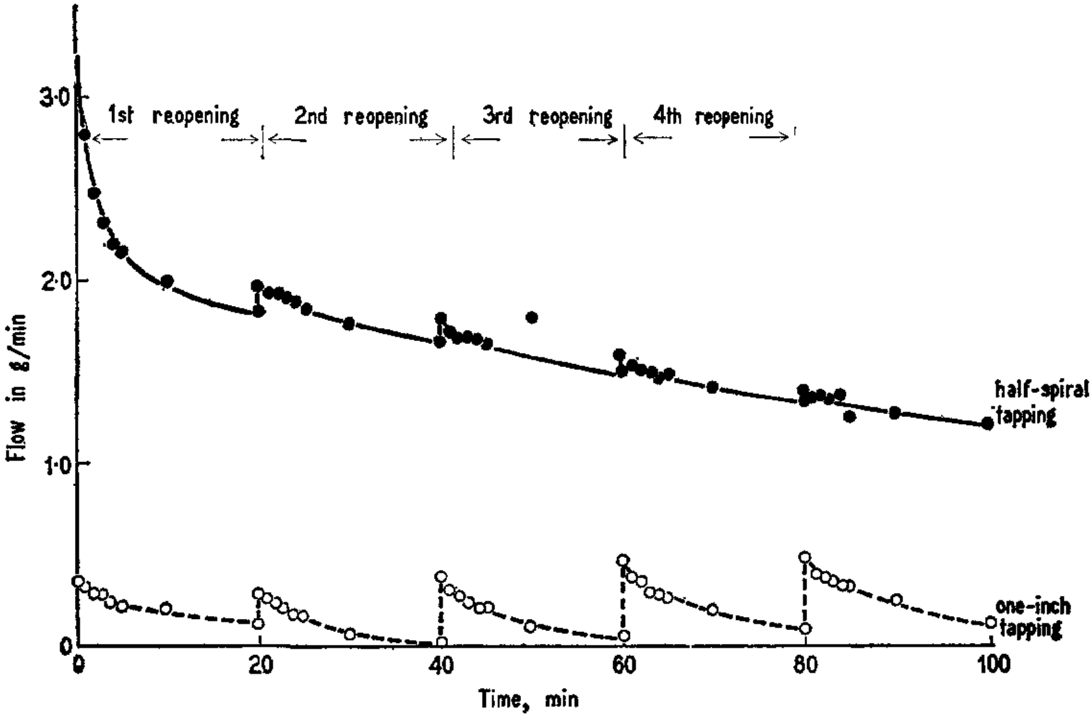
half spiral cut with which it was compared had no detectable influence *(Table 3)*.

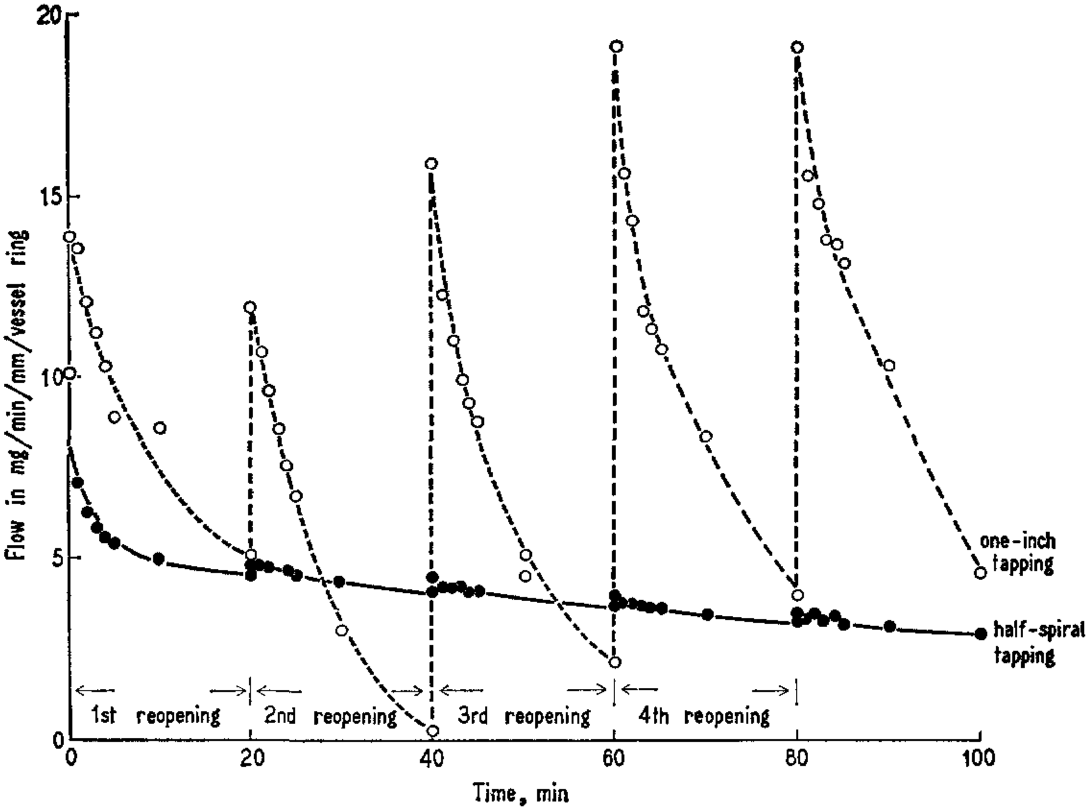
A graphical representation of these results is given in *Figures 1(a)* and *2(a)* where the complete flow curves are given for two trees (RRIM 501 and PR 107) for the longest and shortest cuts. The height of the 'steps' in these curves is an indication of intensity of plugging.

The results shown in *Figures 1(a)* and *2(a)*, though quite clear, are to some degree masked by the very large difference in numbers of vessels between the long and short cuts. They become much more dramatic when calculated to a common basis of flow rate per millimetre of cut length per vessel ring, *i.e.*, to a comparable number of vessels per cut [*Figures 1(b)* and *1(c)*].

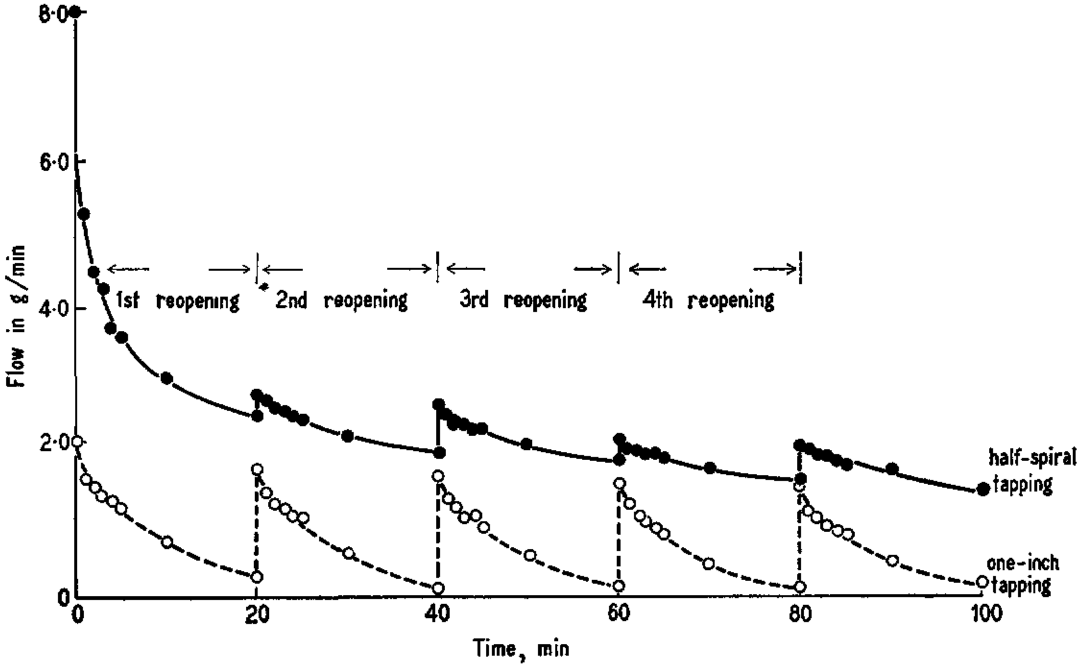
It is possible to derive some indirect indication of changes of turgor pressure in the tree from repeated tapping experiments. The latex is at a pressure of 10–14 atmospheres in the tree before tapping (BUTTERY AND BOATMAN, 1964). MILFORD *et al.* (1969) showed that turgor pressure falls immediately after tapping, but begins to rise as plugging sets in, presumably because pressure builds up behind the obstruction. Other things being equal, the outflow from a given vessel immediately after tapping would be largely governed by turgor pressure. Thus, the peaks shown in a flow curve from a repeated tapping experiment are an indication not only of the resurgence of flow, but also of the recovery of turgor pressure which plays a major part in such resurgence. In a further experiment on the same trees of clones RRIM 501 and PR 107 as were previously used, the flows over the first minute after each reopening were compared with the flow in the minute following the initial tapping. The results are shown in *Table 4*.

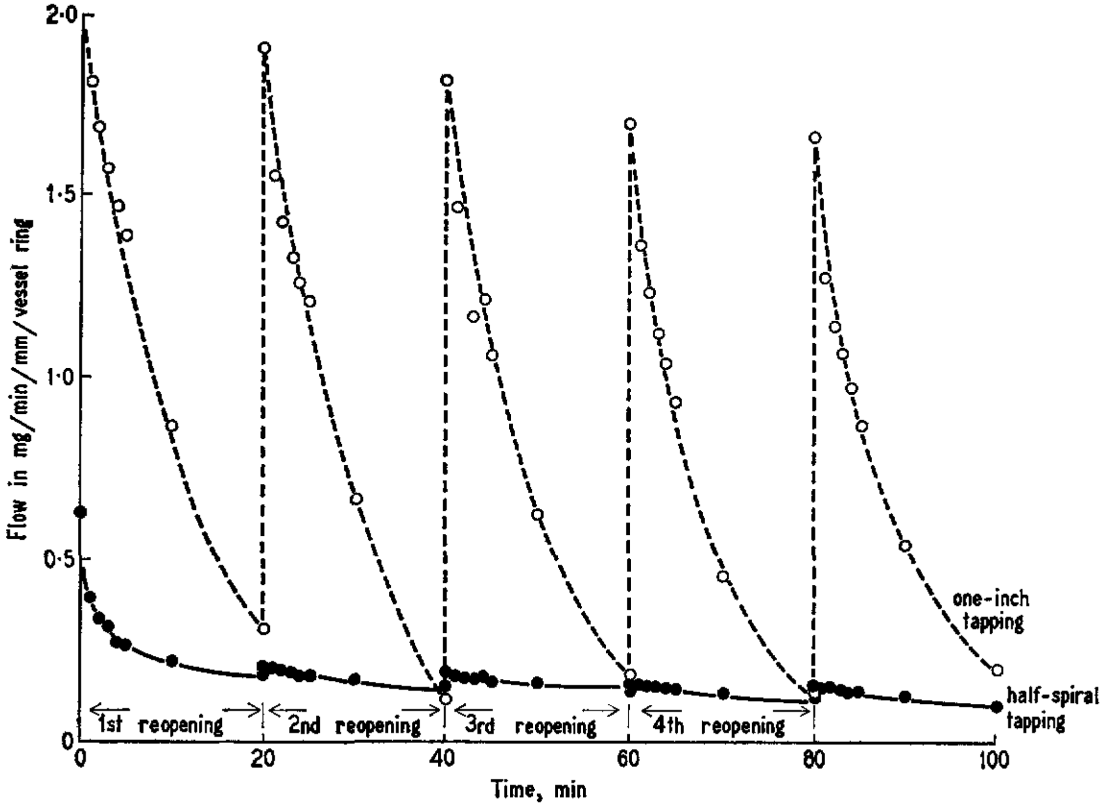
The results *(Table 4)* contain two points of interest. Firstly, the mean percentage recovery of flow (and, by implication, of turgor pressure) is higher for the shorter cuts than for the longer ones. Secondly, in successive cuts on the same tree, the trend is towards successively lowered flow recovery for each reopening, suggesting that cumulative fluid losses are affecting turgor recovery. This trend is displayed





Figures 1(a) and 1(b). Flow curves for repeated tapping for a tree of Clone RRIM 501 for half spiral and one-inch cuts. Figure 1(a) shows flow from each of the two cuts. Figure 1(b) shows the flow per mm of cut per vessel ring for each of the two cuts.





Figures 2(a) and 2(b). Flow curves for repeated tapping of a tree of Clone PR 107 for half spiral and one-inch cuts. Figure 2(a) shows the flow from each of the two cuts. Figure 2(b) shows the flow per mm of cut per vessel ring for each of the two cuts.

TABLE 4. COMPARISON OF FLOW* IMMEDIATELY AFTER RETAPPING AT 20-MINUTE INTERVALS WITH FLOW IMMEDIATELY AFTER INITIAL TAPPING

Tree		Length of cut	Flow for first minute after each retapping as percentage of flow for first minute after initial tapping				Arithmetic mean for each group
			1st	2nd	3rd	4th	
PR 107	(A)	Half spiral	25.4	21.3	19.7	15.6	23.5
	(A)	,, ,,	34.6	25.8	25.2	20.2	
		(Mean)	(30.0)	(23.6)	(22.5)	(17.9)	
PR 107	(A)	3/8 spiral	28.9	31.3	30.7	22.8	36.9
	(A)	,, ,,	27.7	32.7	25.7	22.3	
	(B)	,, ,,	36.0	42.6	34.4	32.8	
	(B)	,, ,,	58.3	50.0	55.5	58.3	
		(Mean)	(37.7)	(39.2)	(36.6)	(34.1)	
PR 107	(A)	1/8 spiral	50.0	69.2	80.8	53.8	51.3
	(A)	,, ,,	52.0	52.0	47.9	41.7	
	(A)	,, ,,	67.6	64.8	62.1	45.9	
	(B)	,, ,,	55.7	48.0	44.2	44.2	
	(B)	,, ,,	66.6	62.9	62.0	51.8	
	(A)	,, ,,	39.1	40.6	34.4	34.4	
	(A)	,, ,,	61.5	67.3	50.0	42.3	
	(B)	,, ,,	47.2	41.7	38.9	36.1	
	(B)	,, ,,	51.6	54.8	40.3	45.1	
		(Mean)	(54.6)	(55.7)	(51.2)	(43.9)	
PR 107	(A)	1-inch	82.7	67.3	78.8	65.4	73.6
RRIM 501	(A)	Half spiral	68.0	60.0	60.0	56.0	51.2
	(B)	,, ,,	48.5	43.6	38.6	34.7	
		(Mean)	(58.3)	(51.8)	(49.3)	(45.4)	
RRIM 501	(A)	1-inch	91.6	90.0	79.4	69.4	100.7
	(B)	,, ,,	85.5	114.5	138.4	136.9	
		(Mean)	(88.6)	(102.3)	(108.9)	(103.2)	

*Results are for cuts of different lengths on trees of clones RRIM 501 and PR 107.

more noticeably for the long cuts than for the short ones, which is hardly surprising since the rate of fluid loss is greater for the longer cuts. In one tree [RRIM 501(B)] for a short (1 inch) cut, this trend is actually reversed, the flow just after the fourth reopening being substantially more than that at the initial tapping.

The likely explanation is that turgor pressures in the tree are subject to two types of variation over the period of such an experiment. Firstly, there are transient variations in factors such as transpiration rate and water availability which can result in detectable differences in turgor even in an undisturbed tree over a period

(SOUTHORN, 1967). Secondly, there are the effects of fluid losses by tapping. For a long cut, the effects of fluid depletion will be dominant, but for very short cuts this is a relatively minor factor and transient changes in local conditions are of major importance. On occasion these can result in a general rise in turgor pressure despite the tapping operation.

DISCUSSION AND CONCLUSIONS

As predicted, the shorter the cut, the more rapid and intense the plugging *(Tables 2* and *3)*. In repeated tapping experiments, where flow recovery just after retapping was compared with initial flow just after the first tapping, there was indirect evidence for cumulative loss of turgor over the period of the experiment in the case of the longer cuts, a trend which was less marked and even reversed on occasion in the case of very short cuts *(Table 4* and *Figure 1)*. It could be argued that, in such experiments, the results might be explained by the more intense plugging already demonstrated for short cuts, and that during the actual flow periods pressure in the vessels might not differ between long and short cuts. Apart from the improbability that turgor pressures could be maintained as readily when a large number of vessels are severed as when the number is small, *Table 1* provides experimental evidence that such an explanation is not tenable; the yield per vessel from a microcut was more than ten times that from a conventional half spiral cut, showing that expulsion forces were very much higher during flow from the shorter cut.

Thus, the expected association of very short cuts with intense plugging, well maintained turgor pressures and high flow rates per vessel (and hence high pressure gradients for an appreciable period within the vessel) has been verified. This association had been predicted previously (SOUTHORN, 1969; YIP AND SOUTHORN, 1968) and the explanation then offered was that there would be a high rate of damage to lutoids within the vessel leading to release of plugging factors if pressure gradients were maintained in the vessel for appreciable periods, and that such conditions were likely to be achieved in short cuts. This hypothesis, which stresses the importance of shear effects in the vessel, is in complete accord with the experimental observations now made.

It is now possible to draw further conclusions from the results obtained, some of which were previously suggested (SOUTHORN, 1969):

(a) The numerical value of 'plugging index' as determined by the method of MILFORD *et al.* (1969) will depend for a given tree on length of cut employed. In these experiments, even trees of RRIM 501, which shows only slight evidence of plugging for a half spiral cut, are subject to intense plugging when the length of cut is reduced.

(b) Treatments, such as yield stimulation by growth regulators which act by reducing intensity of plugging, will produce a response only if the length of cut is sufficiently short for plugging to be a significant factor in flow. It follows that some trees which do not respond to treatments of this type on conventional half spiral tapping, are likely to show a response on a shorter cut. Bearing in mind that the yield per vessel appears to be higher as the length of cut decreases, it would be useful to study whether, for some clones, shorter-than-usual tapping cuts combined with yield stimulation might offer economic advantages. Equally, for stimulated high plugging clones, it is possible that a longer cut than half spiral may be useful.

(c) SOUTHORN (1969) postulated that *Hevea* has at least two distinct physiological mechanisms for terminating flow when vessels are severed. For a small incision, plugging factors intrinsic to the latex would be triggered off to stop flow quickly while turgor pressures remained relatively high. For a long tapping cut, the rapid general loss of turgor due to fluid loss would prevent or reduce the effectiveness of this mechanism, but general loss of turgor would eventually retard flow to a level where coagulation along the bark and back diffusion of coagulants could seal the vessels.

There would seem to be no easy way of interfering with the second mechanism. From the present results it would seem that if some way could be found to inhibit the first (plugging) mechanism for a cut sufficiently short to be within the capacity of the tree to maintain turgor at a reasonable level, then flow should continue at a low rate for a very long period since severance of even a small number of latex vessels opens pathways to an extensive part of the latex bearing system. Since chemical treatments which reduce plugging intensity are already known, this approach offers distinct possibilities for further work.

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