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SHORT COMMUNICATION

Quantification of Latex Vessel Plugging by the 'Intensity of Plugging'

H.Y. YEANG AND MOHD. NAPI DAUD

Based on theoretical considerations, the 'intensity of plugging' is preferred to 'plugging index' as a measurement of latex vessel plugging.

Boatman[1] observed that when a tree was re-tapped on the same tapping cut at intervals before latex flow from the preceding tapping had stopped, there was a marked recovery of the flow rate at each re-tapping. This suggests that latex vessel plugs, which form a physical impediment to the latex outflow, begin to form within a few minutes after tapping. A large proportion of the plugs must be located very near the cut ends of the vessels (*i.e.* at the tapping cut) since it is removed by the excision of a 1 mm shaving of the bark when the tree is tapped. Latex vessel plugging is important in *Hevea* productivity as it determines the duration of flow and, hence, yield output.

The most common means of quantifying the propensity of trees to latex vessel plugging is by the use of the 'plugging index', a concept introduced by Paardekooper and Samosorn[2] and Milford *et al.*[3] Paardekooper and Samosorn[2] demonstrated that the rate of latex flow after tapping could be expressed by the exponential function $y = b.e^{-at}$ where the flow rate 'y' after an interval 't' from the time of tapping is a function of the initial flow rate 'b' and the time-flow constant 'a' which (multiplied by 100) is the plugging index. In practice, the plugging index is expressed as:

$$\frac{\text{Initial flow rate (Volume per minute)}}{\text{Yield (Volume)}} \times 100$$

(see Paardekooper and Samosorn[2] for the derivation of this formula).

The main weakness of the plugging index as a measure of latex vessel plugging is that the exponential function on which the plugging index is based essentially describes the pattern of flow decrease when the tree is tapped; it does not monitor latex vessel plugging *per se*. (In this respect, the 'plugging index' is a misnomer.) Besides latex vessel plugging, other factors (e.g. turgor loss) also reduce latex flow and the resultant effect of these factors — together with plugging — control the flow rate. Equating the pattern of latex flow to that of plugging necessitates the untenable assumption that the progressive decrease in latex flow after tapping is due solely to latex vessel plugging. Two other indices of latex flow, the 'flow ratio'[4] and the 'flow restriction index'[5,6] are similarly based on the net effect of latex flow regulation by various factors; they do not measure plugging specifically.

Principles Governing Proposed Hypothesis

Measurement of latex vessel plugging should be based on a selective characteristic of plugging that is not generally common to other factors that also restrict flow rate. Southorn and Gomez[7] used a method to determine the propensity to latex vessel plugging that was based on Boatman's[1] observation that flow rate increased immediately upon removal of latex vessel plugs by re-tapping the tree. This method, termed the 'intensity of plugging' involved re-tapping the tree at prescribed

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intervals before flow from the preceding tapping had stopped. The intensity of plugging was calculated as:

$$\frac{\text{(Weight of latex exuded 1 min after re-tapping)} - \text{(Weight of latex exuded 1 min before re-tapping)}}{\text{Weight of latex exuded 1 min after re-tapping}} \times 100$$

Re-tapping the tree is deemed to remove latex vessel plugs that have formed. The difference in flow rate just before and just after re-tapping thus represents the extent to which flow has been impeded up to the time of re-tapping. The intensity of plugging is generally free from interference by other flow restricting factors as it is based on two readings made very close to one another (*i.e.* 1 min before re-tapping and 1 min after). As it is reasonable to assume that the physiological state in the tree relating to the status of the drainage area, latex depletion in the vessels, panel turgor pressure, *etc.* does not change significantly over this short interval, the difference in the flow rates before and after re-tapping is attributable mainly, if not wholly, to the removal of latex vessel plugs.

The validity of the intensity of plugging as a measure of latex vessel plugging lies on the premise that most of the plugs are formed very near the cut ends of the vessels (*i.e.* at the tapping cut) and that they are removed with the shaving of the bark excised when the tree is tapped. Apart from circumstantial evidence from the studies of Boatman pointing to the occurrence of plugging at the tapping cut, direct evidence for the formation of plugs near the surface of the tapping cut was obtained by Southorn[8] using the electron microscope. However, it is not clear from Southorn's study as to how far from the tapping cut internal plugs could lie (his survey only concerned portions of latex vessels lying a few tenths of a millimetre from the surface of the tapping cut).

METHODOLOGY AND RESULTS

To ascertain if all or almost all the latex vessel plugs present at the tapping cut are indeed removed with the bark shaving during tapping, the initial flow rates immediately after tapping (or re-tapping) were compared when one, two or three shavings of bark were excised during tapping (equivalent to the removal of bark shavings of normal thickness or two and three times the thickness of a normal shaving). As shown in *Table 1*, there was no significant increase in flow rate in a high plugging clone (PR 107) and a low plugging clone (RRIM 701) with increased bark consumption when the trees were tapped initially or (in another experiment) re-tapped 50 min after the initial tapping. It may be inferred, therefore, that normal tapping effectively removes all or almost all of the plugs formed at the tapping cut.

In determining the intensity of plugging, Southorn and Gomez[7] re-tapped a tree four times at 20 min intervals and the latex collected before and after re-tapping was weighed. As such, they considered the procedures 'too complex to be done on more than one or two trees at a time'. These procedures have to be simplified before they can be adopted for routine field application. Accordingly, trials were carried out whereby the tree was re-tapped only once or twice and the flow rates just before and after re-tapping were determined by volume measurement rather than by weighing. In an experiment, the intensity of plugging during the early flow after tapping (IP_{15}) was calculated for eight clones *(Figure 1)* from measurements made when the trees were re-tapped 15 min after the initial tapping. The trees in all the clones were of the same age and tapped on *Panel BO-2*. Plugging propensity during the late flow (IP_{15-45}) was determined as the intensity of plugging calculated from measurements made when the trees were again re-tapped 45 min from the initial tapping. The intensity of plugging over these two periods were positively correlated to each other *(Figure 1)* and to the plugging index of the same trees *(Figure 1)*. In another experiment, the intensity of plugging (IP_{50}) in fifteen trees of PR 107 (a high plugging clone) tapped on

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TABLE 1. EFFECT OF THICKNESS OF BARK SHAVING EXCISED DURING TAPPING ON THE INITIAL FLOW RATE

No. of shavings excised	First 5 min flow rate on initial tapping (ml/min)		First min flow rate on re-tapping 50 min after initial tapping[a] (ml/min)	
	PR 107	RRIM 701	PR 107	RRIM 701
1	5.5±0.3	6.0±0.4	5.5±0.4	6.5±0.5
2	5.6±0.3	5.9±0.4	5.5±0.3	5.9±0.4
3	5.5±0.3	5.6±0.3	5.5±0.4	6.4±0.4

Values presented are the means ± standard errors of twenty-four trees per treatment.

[a]One shaving excised at the initial tapping

Panel BO-2 and fourteen trees of RRIM 701 (a low plugger) tapped on *Panel BO-1* was determined by re-tapping the trees once at the fiftieth min after the initial tapping. The trees within each clone were of the same age. Significant positive correlations were obtained between the intensity of plugging and the plugging index in both clones *(Figure 2)*. The between-clone and within-clone correlations between these two variables indicate that, not surprisingly, latex vessel plugging contributes significantly to the overall inhibition of latex flow when the tree is tapped.

For measurement of the intensity of plugging to be of practical use, it should be sensitive in detecting differences in the susceptibility to latex vessel plugging between clones or trees. The 'Non-Central F' Test[9] was applied to assess the relative effectiveness of the intensity of plugging in this respect. A comparison could be made from the calculated values of ϕ which varied directly with the resolving power of the intensity of plugging in differentiating between individual clones or trees. Sensitivity of the intensity of plugging measurements was enhanced by increasing the number of replicate measurements. This had the effect of reducing the random (error) variation — as denoted by the lower coefficient of variation — leading to an increase in the value of ϕ *(Table 2)*. A comparison of intensity of plugging measurements for the early flow and late flow showed that whereas the coefficients of variation were essentially similar for the two sets of measurements, clonal differences in the intensity of plugging were better defined during the late flow *(Table 3)*. In *Tables 2* and *3*, the intensity of plugging values — which are essentially percentages — were transformed to angles (arcsin transformation) for computation. (Transformation was not carried out for the data presented in *Figures 1* and *2* as the correlations calculated from transformed or untransformed data were found to be largely identical.)

TABLE 2. EFFECT OF INCREASING THE NUMBER OF REPLICATE INTENSITY OF PLUGGING MEASUREMENTS ON THE COEFFICIENT OF VARIATION AND THE VALUE OF ϕ IN THE 'NON-CENTRAL F' TEST

Item	$IP_{50}(A)$	$IP_{50}(B)$	IP_{50} Mean of A and B
Coefficient of variation (%)	25.6	25.3	16.4
ϕ	0.30	0.42	0.56

Two intensity of plugging measurements (A and B) were made per week for three weeks on fourteen RRIM 701 trees.

Coefficient of variation was calculated from the residual variance after extracting tree and replicate week effects.

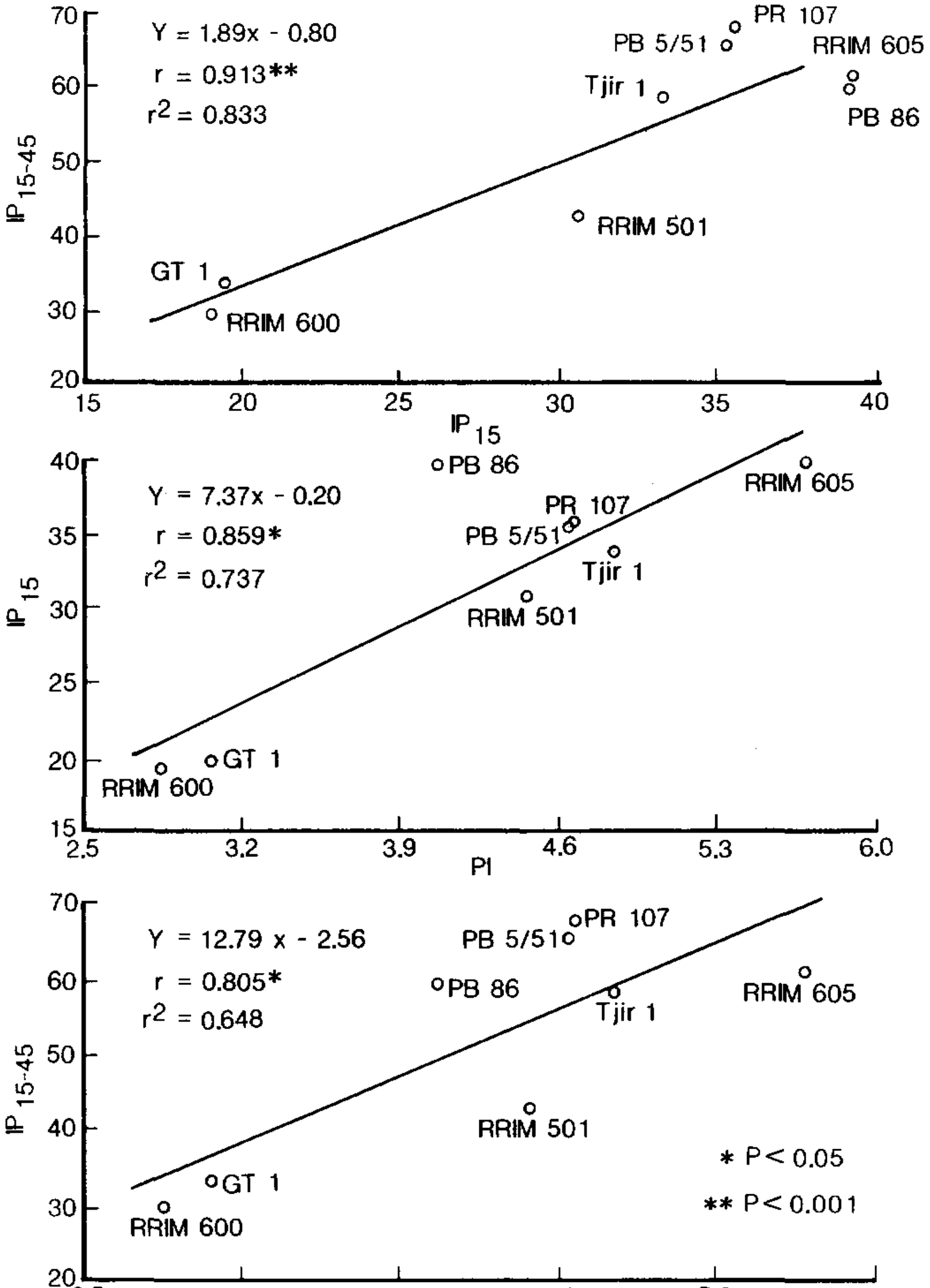

Figure 1. Correlations between the plugging index (PI), the intensity of plugging for the early flow (IP_{15}) and the intensity of plugging for the late flow (IP_{15-45}) in eight clones. Each point on the scatter diagrams is the mean of 6 trees×4 replicates.

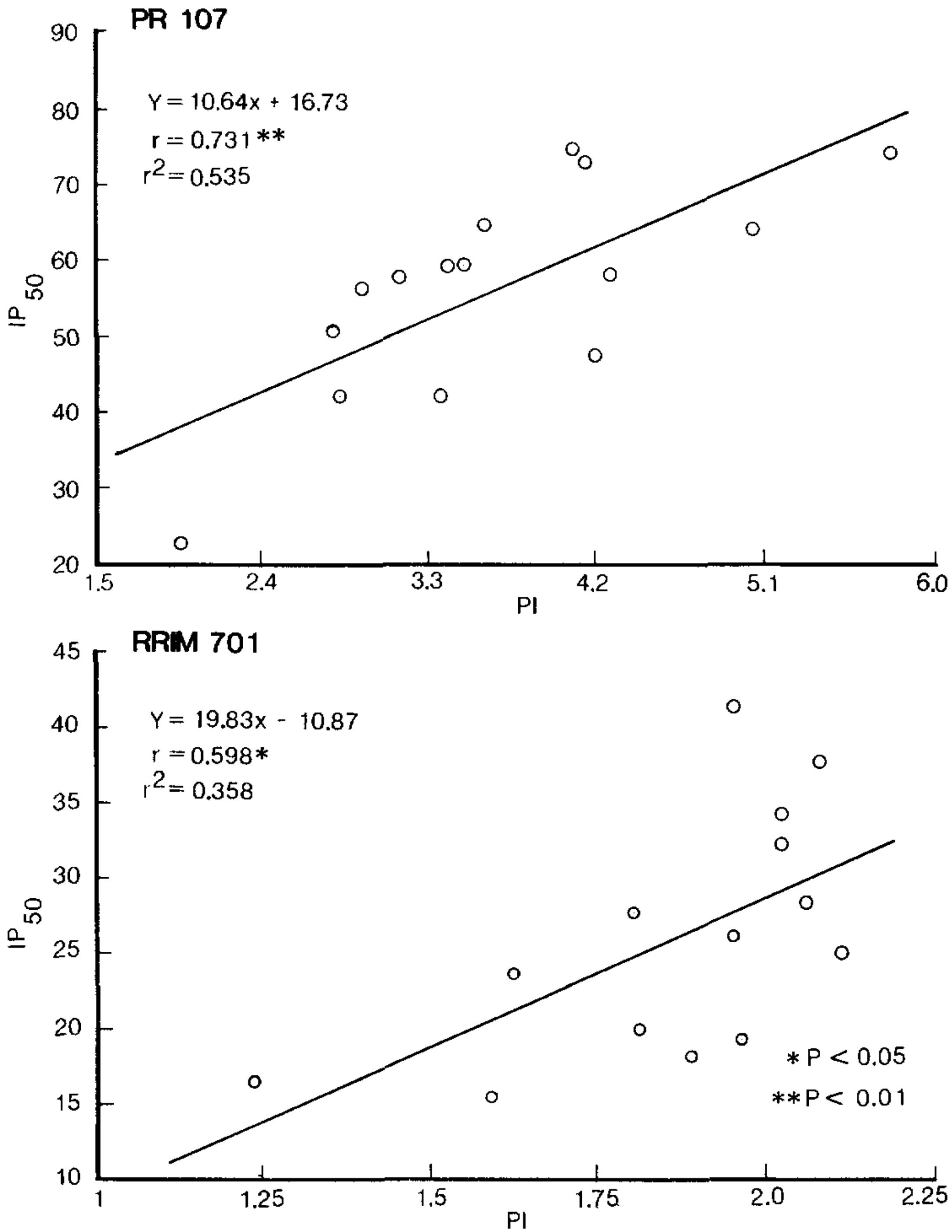

Figure 2. Correlations between the plugging index (PI) and the intensity of plugging (IP_{50}) in PR 107 and RRIM 701. Each point on the scatter diagrams is the mean of 3 (PR 107) or 6 (RRIM 701) replicates.

TABLE 3. COEFFICIENT OF VARIATION AND VALUE OF ϕ IN THE 'NON-CENTRAL F' TEST FOR INTENSITY OF PLUGGING MEASUREMENTS FOR THE EARLY FLOW AND LATE FLOW

Item	IP_{15}	IP_{15-45}
Coefficient of variation (%)	32.5	30.9
ϕ	0.74	1.00

Calculations were based on 6 trees × 4 replicates for each of eight clones: Tjir 1, PR 107, GT 1, PB 86, PB 5/51, RRIM 501, RRIM 600, RRIM 605.
Coefficient of variation was calculated from the residual variance after extracting clone, replicate and interaction effects.

The mean additional yield for the eight clones arising from re-tapping the trees twice was 54% that of normal tapping. Hence, re-tapping the tree for the purpose of determining the intensity of plugging should not stress the tree excessively provided that the determinations are appropriately spaced apart. Similarly, the very slight increase in bark consumption should be, for all practical considerations, negligible.

CONCLUSION

The intensity of plugging is to be preferred to the plugging index where the propensity to latex vessel plugging is specifically being studied although the latter remains useful in many applications as a simple indicator of cumulative flow restriction.

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