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Factors Influencing the Colloidal Stability of Fresh Clonal Hevea Latices as Determined by the Aerosol OT Test

ESAH YIP and J.B. GOMEZ

Fresh Hevea *latices from five clones were studied. Latex stabilities as measured by the Aerosol OT test showed very marked clonal differences. Influence of some of the relevant factors on this parameter was investigated.*

The levels of divalent cations, particularly magnesium, in the non-rubber phase, apart from being markedly different between clones, exhibited a statistically significant inverse relationship with latex stability of the various clones. Significant clonal differences were also found in the contents of phosphorus in latex, present mostly as phosphate ions. A positive correlation between phosphorus content and the stability of the clonal latices was observed. Examinations of the overall effect of the antagonistic actions between the divalent cations and phosphorus, expressed as ratios Mg/P and (Mg + Ca)/P, indicated that high latex stability was associated with low ratio and vice versa.

Further investigations confirmed the inverse relationship between the latex stability index and the plugging index of different clones. Although plugging index showed relationship with latex yield of the trees and their response to yield stimulation, such correlations have not been established with the latex stability index.

Fresh latex of *Hevea brasiliensis* is a polydisperse system in which charged particles of different types are suspended in a predominantly anionic ambient C-serum. Its two main particulate phases consist of the rubber hydrocarbon particles and the membrane bound bodies known as lutoids. Flocculation of the latex particles during latex flow, brought about mainly by electrostatic interactions between the anionic rubber particle surface and the cationic contents of the lutoid serum (known as B-serum)[1], released by damaged lutoids[2,3], is believed to initiate latex vessel plugging and subsequently curtail the flow of latex. It has been suggested[4] that the inherent colloidal stability of *Hevea* latex is an influencing factor controlling latex flow, and that differences in the extent of plugging between clones could be attributed to differences in the stability between clonal latices.

A test for assessing the colloidal stability of fresh latex has been developed by Yip and Gomez[4], which involves the gelling of fresh latex by an anionic surfactant, sodium dioctylsulphosuccinate (Aerosol-OT). It has been shown that the mechanism for the destabilising reaction apparently involves the displacement of the rubber particle surface layer by the surfactant, giving them an anionically charged soap surface. Being surface active, the Aerosol OT also damages the lutoid particles, releasing their serum containing, among other substances, considerable

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quantities of magnesium and calcium ions, which then interact with the rubber particles presumably forming insoluble magnesium and calcium soap, hence linking up the particles into a gel[4,5]. The counter ions present in C-serum, particularly phosphates, on the other hand, could exert certain inhibiting effects on this gelling reaction[5]. The gelling reaction is therefore dependent on various latex properties such as: rubber particle surface area and properties of this surface; resistance of lutoids to damage; presence of divalent cations, Mg^{++} and Ca^{++}, in the latex sera; and, activity of counter ions, notably phosphates, in latex. It is generally accepted that these properties are also factors affecting the colloidal stability of fresh latex. Thus, the test provides a method for assessing the overall stability of latex. With the test, significant clonal differences in the latex stability so determined have been observed. It is thought that these differences could be attributed to variation in latex properties between clones. The present work was undertaken to study some of these properties and their influence on latex stability of different clones.

Earlier observations by the authors[4] also suggested a relationship between latex stability and the extent of latex vessel plugging, as measured by the plugging index[6]. The present study was therefore extended to further examine this relationship. The effects, if any, of yield stimulants and rainfall on the latex stability were also investigated.

EXPERIMENTAL

Eighty trees of clones GT 1, PB 86, RRIM 501, RRIM 600 and Tjir 1, in *Field 14D* at the Rubber Research Institute of Malaysia Experiment Station at Sungei Buloh were selected. All trees were on the S/2.d/2 tapping system on *Panel B.* Latex flow fractions were collected at 15 min intervals after tapping, directly into glass vessels surrounded by ice. Each flow fraction was pooled from a group of trees of the same clone.

For investigations on the effects of yield stimulation, the sixteen trees of each clone were divided into two equal groups. One group of these trees was treated with ethephon (containing 10% of 2-chloroethylphosphonic acid as the active ingredient, incorporated into palm oil) while the other group acted as the control and was treated with only the palm oil base containing no stimulant. Application of the yield stimulant was carried out at two-monthly intervals.

The Aerosol OT stability test was carried out with four latex flow fractions of each clone as described by Yip and Gomez[4]. The mean stability index was determined by averaging stability indices obtained for all four flow fractions of each clone for each collection.

Lutoid fraction and C-serum were prepared from latex collected during the first half-hour flow after tapping, by ultracentrifugation[7]. B serum was obtained by subjecting the lutoid fraction to alternate freezing and thawing followed by further ultracentrifugation[4].

Magnesium and calcium concentrations in latex sera were determined by atomic absorption spectroscopy after digestion of the samples with concentrated nitric acid and removal of the interfering ions[8]. Phosphorus contents of latex and rubber cream were determined by the phosphomolybdate colorimetric method[9]. Measurements of diameter and total surface area of rubber particles were carried out using electron microscopy after fixation of the sample in 2% osmium tetroxide. Plugging index was determined according to Milford *et al.*[6], with a modification by Yip and Gomez[4]. The plugging index as measured was

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

where the measurements were pooled values of a group of trees from each clone.

RESULTS

Rubber Particle Surface Area

Fresh latices collected during the first half-hour flow after tapping from unstimulated trees of five clones were examined. Rubber particle diameters, particle number and total surface area were determined in all cases using the electron microscope method. Sampling was done once a month over a period of eighteen months. Mean values obtained for the five clones are shown in *Table 1*. It can be seen that none of the parameters measured exhibited any marked clonal differences, with the exception of total surface area per millilitre of latex showing significantly higher value for RRIM 501 than for RRIM 600 and PB 86. Stability indices of the corresponding latices were also determined over the same experimental period. Mean values for the five clones showed the following decreasing order: RRIM 501 (7.7) > GT 1 (5.8) > RRIM 600 (4.6) > PB 86 (4.3) > Tjir 1 (3.1). The influence, if any, of rubber particle surface area, as measured by this method, on the Aerosol OT stability of the five clonal latices investigated was not apparent.

Magnesium and Calcium Ions

Magnesium and calcium levels in B-serum, lutoid fraction and the non-rubber phase (lutoid fraction + C-serum) in constant volumes of latices from unstimulated trees were investigated. A total of 215 latex collections (forty-three per clone) was examined over a period of twenty-five months. Determinations of stability indices of the corresponding latices were carried out simultaneously. *Table 2* gives an analysis of variance of magnesium levels in the non-rubber phase of latices from five clones. Clonal dif-

TABLE 1. PARTICLE DIAMETER, NUMBER AND TOTAL SURFACE AREA OF RUBBER PARTICLES FOR FIVE CLONES

Clone	Number average diameter (Å)	Number of particles/ml latex × 10^{12}	Total surface area/ml latex × 10^{20} (Å^2)
RRIM 501	2 372	7.87	2.52
GT 1	2 160	8.66	2.41
Tjir 1	2 110	9.41	2.38
RRIM 600	2 118	8.62	2.18
PB 86	2 221	6.73	2.17
S.E. (±)	121	1.72	0.12
L.S.D.	340	4.82	0.34

TABLE 2. ANALYSIS OF VARIANCE AND MEAN MAGNESIUM LEVELS IN THE *NON-RUBBER PHASES IN 100 MILLILITRES OF LATEX FOR FIVE CLONES*

Item	Mg^{++} concentration in B-serum[a]	Mg^{++} content of B-serum[b]	Mg^{++} content of lutoid fraction[b]	Mg^{++} content of non-rubber phase[b]
Mean squares				
Clones 4 degrees of freedom	27 790***	2 843 119***	383 628***	5 738 560***
Days 42 degrees of freedom	1 252***	95 502***	125 840***	1 708 895***
Errors 168 degrees of freedom	216	21 891	32 496	47 698
S.D.	14.7	148.0	180.3	218.4
Mean	65.3	656.6	790.2	1 138.8
C.V. (%)	22.5	22.5	22.8	19.2
Mean level				
RRIM 501	33	267	322	532
PB 86	50	533	648	1 040
GT 1	58	770	933	1 360
RRIM 600	91	908	1 076	1 414
Tjir 1	94	804	971	1 348
S.E. (±)	2	23	28	34
L.S.D. (P= 0.05	6	63	78	93

[a]Mean level in millimolar

[b]Mean level in 100 ml of latex in micromoles

***Significant at $P < 0.001$

Lutoid fraction = B-serum + lutoid residues

Non-rubber phase = lutoid fraction + C-serum

ferences in magnesium concentration of B-serum, in magnesium contents of B-serum, lutoid fraction and non-rubber phase were highly significant, with clone RRIM 501 showing lowest values in all the parameters measured. Day-to-day variation was also highly significant in all cases for the five clones.

Mean stability indices of the corresponding clonal latices gave average values showing a decreasing order similar to that observed earlier: RRIM 501 (7.7) > GT 1 (6.2) > RRIM 600 (4.2) > PB 86 (4.2) > Tjir 1 (3.0). A study of correlations between the various magnesium levels and the Aerosol OT latex stability indicated that they were highly correlated (inversely) between clones (*Table 3*). This relationship was however not always observed within clones.

The contents of calcium ion in both B-serum and lutoid fraction were found to be considerably lower than those of magnesium, as expected[10], and the concentration in C-serum was very often too low to be detected. Consequently, the level of calcium in C-serum was not determined in this study. Two hundred latices (forty per clone) were investigated. Results expressed as mean calcium levels in B-serum and lutoid fraction from 100 ml of fresh latex for five clones can be seen in *Table 4*, which also shows the analysis of variance of the data obtained. It is evident that clonal differences were significant in the calcium concentration of B-serum, total calcium in B-serum from 100 ml of latex and total calcium in non-rubber phase from the same volume of latex. Further statistical analysis of the data revealed that relationships between these parameters and latex stability were not significant, with the exception that RRIM 501 latex, the most stable clonal latex among the five studied, had the lowest calcium concentration as well as the lowest total calcium contents.

Phosphorus Content

Phosphorus levels in each of the five clonal latices and their corresponding rubber phases obtained from constant volumes of fresh latices were measured once a month. Determinations of mean stability index were carried out simultaneously. Altogether sixty latex collections (twelve per clone) were investigated.

Figure 1 illustrates the levels of phosphorus of fresh latices for five clones over

TABLE 3. CORRELATIONS BETWEEN MEAN STABILITY INDEX AND MAGNESIUM LEVELS IN NON-RUBBER PHASES OF LATICES FROM FIVE CLONES

Clone	Correlation of mean stability index with			
	Mg^{++} conc. in B-serum	Mg^{++} content of B-serum[a]	Mg^{++} content of lutoid fraction[a]	Mg^{++} content of non-rubber phase[a]
Within clone				
RRIM 501	0.079 NS	0.067 NS	0.029 NS	−0.245 NS
GT 1	0.162 NS	−0.085 NS	−0.155 NS	−0.150 NS
RRIM 600	−0.224 NS	−0.263 NS	−0.343*	−0.397**
PB 86	−0.409**	−0.471**	−0.517**	−0.579**
Tjir 1	−0.184 NS	0.058 NS	0.097 NS	0.101 NS
Between clones	−0.521***	−0.502***	−0.526***	−0.539***

[a]Quantity of B-serum, lutoid fraction or non-rubber phase present in 100 ml of fresh latex

***Significant at $P < 0.001$

**Significant at $P < 0.01$

*Significant at $P < 0.05$

NS = Not significant

TABLE 4. ANALYSIS OF VARIANCE AND MEAN CALCIUM LEVELS IN B-SERUM AND LUTOID FRACTION IN 100 MILLILITRES OF LATEX FOR FIVE CLONES

Item	Ca^{++} concentration in B-serum[a]	Ca^{++} content of B-serum[b]	Ca^{++} content of lutoid fraction[b]
Mean squares			
Clones – 4 degrees of freedom	0.73**	435.79***	594.71***
Days – 39 degrees of freedom	1.39***	186.32***	238.90***
Errors – 156 degrees of freedom	0.21	25.53	28.63
S.D.	0.45	5.05	3.35
Mean	1.34	13.91	17.14
C.V. (%)	33.74	36.32	31.22
Mean level			
RRIM 501	1.19	9.47	11.92
RRIM 600	1.24	12.50	14.95
GT 1	1.33	17.36	20.82
Tjir 1	1.45	13.24	16.77
PB 86	1.51	17.00	21.24
S.E. (±)	0.07	0.80	0.54
L.S.D. (P = 0.05)	0.20	2.21	1.51

[a]Mean level in millimolar
[b]Mean level in 100 ml of latex in micromoles
***Significant at $P < 0.001$
**Significant at $P < 0.01$

the experimental period, the levels in the corresponding non-rubber phase (calculated by difference) and rubber phase, over the same period. It is apparent that considerable differences existed between clones in the case of the fresh latex and the non-rubber phase. This difference was less marked in the rubber phase however. Analyses of variance of the data confirmed these observations, showing highly significant clonal differences in both the whole latex and the non-rubber phase, and a lesser degree of significance in the case of the rubber phase (*Table 5*).

About 28% to 38% of the total phosphorus in latex was found in the rubber phase and 62% to 72% in the non-rubber phase, values being consistent with those reported by Cook and Sekhar[11]. The amounts of phosphorus estimated for 100 ml of latex and the non-rubber phase in the same volume of latex varied from clone RRIM 501 showing the highest values to clone PB 86 showing the lowest values in the following decreasing order: RRIM 501 > GT 1 > RRIM 600 > Tjir 1 > PB 86. This is somewhat similar to that obtained for mean stability indices of the corresponding latices for the five clones: RRIM 501 (7.1) > GT 1 (5.8) > RRIM 600 (4.2) > PB 86 (3.5) > Tjir 1 (2.9). Highly significant correlations have in

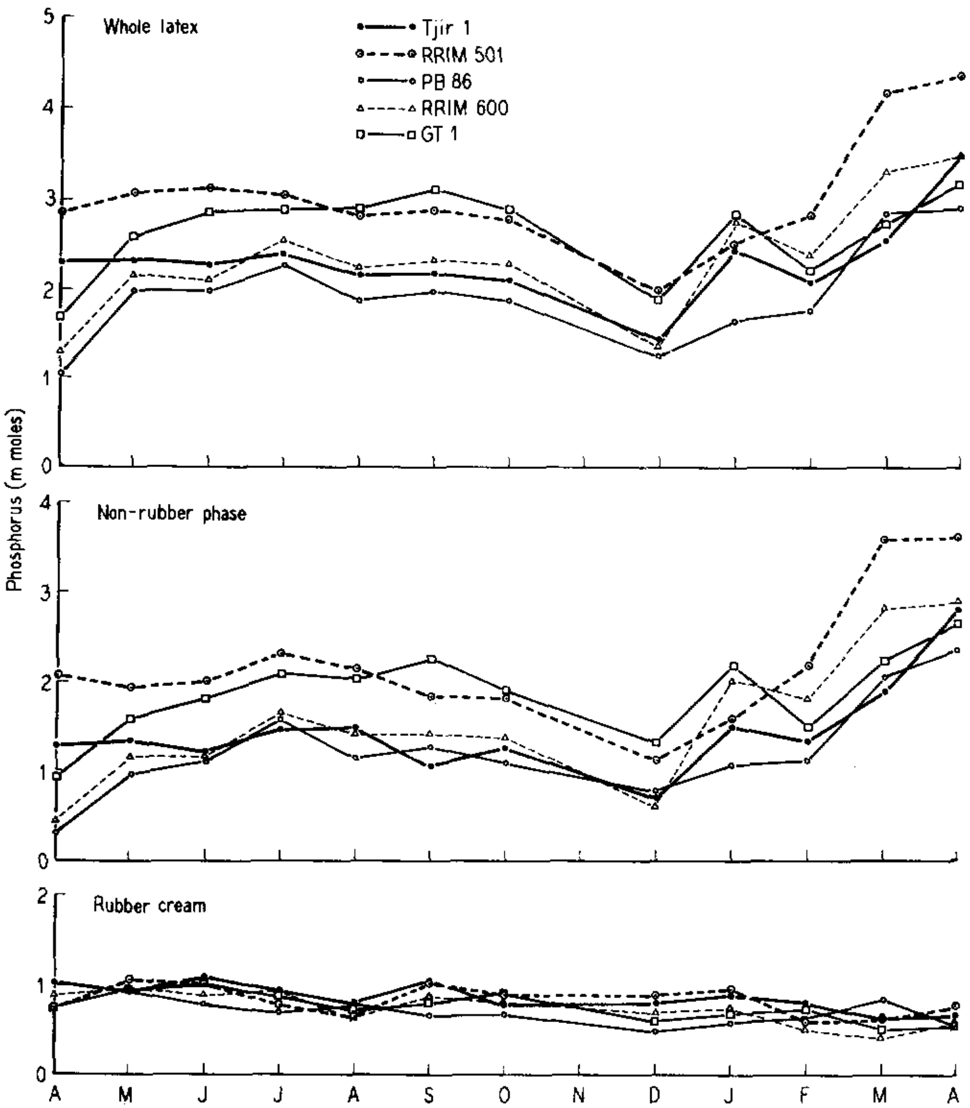

Figure 1. Day-to-day variation of total phosphorus in 95 ml of fresh latex for five clones in Field 14D, variation of total phosphorus in non-rubber phase from 95 ml of fresh latex for the same five clones, and variation of total phosphorus in the corresponding rubber phase from equal volumes of the same five clonal latices.

fact been found between the mean stability indices and phosphorus contents of both whole latex and the non-rubber phase for the five clones *(Table 6)*. Such correlations were however not observed within clones as well as in the case of phosphorus in the rubber phase. The phosphorus contents of latices and the non-rubber phases were higher during the period January – April. This may be a reflection of changes in latex as a consequence of wintering.

TABLE 5. ANALYSIS OF VARIANCE AND MEAN PHOSPHORUS CONTENTS IN WHOLE LATEX AND LATEX PHASES FOR FIVE CLONES

Item	Whole latex	Rubber phase	Non-rubber phase
Mean squares			
Clones — 4 degrees of freedom	1.97***	0.05*	1.67***
Days — 11 degrees of freedom	1.28***	0.06*	1.49***
Errors — 44 degrees of freedom	0.80	0.01	0.91
S.D.	0.28	0.10	0.30
Mean	2.45	0.80	1.65
C.V. (%)	11.6	12.3	18.2
Mean level in 100 ml of fresh latex (m mole)			
RRIM 501	3.03	0.85(28)	2.18(72)
GT 1	2.64	0.77(29)	1.87(71)
RRIM 600	2.33	0.71(30)	1.62(70)
PB 86	1.95	0.72(37)	1.23(63)
Tjir 1	2.31	0.87(38)	1.44(62)
S.E. (±)	0.08	0.03	0.08
L.S.D. ($P = 0.05$)	0.23	0.08	0.25

Figures within brackets are values of percentage of total phosphorus.

***Significant at $P < 0.001$
*Significant at $P < 0.05$

TABLE 6. CORRELATION OF MEAN STABILITY INDICES WITH PHOSPHORUS CONTENTS OF LATEX AND LATEX PHASES FOR FIVE CLONES

Clone	Correlation of mean stability index with		
	P in whole latex	*P in rubber phase*	*P in non-rubber phase*
Within clone			
RRIM 501	–0.563 NS	0.031 NS	0.520 NS
GT 1	0.085 NS	0.219 NS	0.028 NS
RRIM 600	0.510 NS	–0.546 NS	0.550 NS
PB 86	0.534 NS	0.546 NS	0.427 NS
Tjir 1	0.122 NS	0.519 NS	0.025 NS
Between clones	0.438***	0.068 NS	0.410**

***Significant at $P < 0.001$
**Significant at $P < 0.01$
NS = Not significant

Ratios of Magnesium and Calcium to Phosphorus

The antagonistic effect between magnesium ion, with or without calcium ion, and phosphorus was studied by expressing the data as ratios of these cations (available in latex sera) to total phosphorus in latex or to phosphorus content of the non-rubber phase, that is Mg/P or (Mg + Ca)/P. Although more results were available for magnesium, calcium and mean stability index, comparison was limited to sixty latex collections (twelve collections per clone) for which the phosphorus contents were investigated. Results are shown in *Table 7*. It can be seen that clonal differences and day-to-day variation of all the ratios examined were highly significant, except for (Mg + Ca)/P (non-rubber) which was comparatively less significant.

The correlations between the mean stability indices and the four ratios are illustrated in *Figures 2* and *3*. They were all significantly interrelated (inversely), the coefficients of correlation being of higher values in the case of total phosphorus in whole latex, as compared to those of the non-rubber phase. This suggests that total phosphorus in latex has more influence over latex stability than that in the non-rubber phase alone. The presence of calcium ion in the ratios expressed appeared to have very little effect on the correlation coefficients obtained. This is likely to be attributed to the relatively much

TABLE 7. ANALYSIS OF VARIANCE AND MEANS OF RATIOS MG/P AND (MG + CA)/P FOR FIVE CLONES

Item	Mg/P		(Mg + Ca)/P	
	Latex	Non-rubber phase	Latex	Non-rubber phase
Analysis of variance				
Clones – 4 degrees of freedom	0.40***	1.83***	0.43***	1.54**
Days – 11 degrees of freedom	0.19***	1.84***	0.19***	0.67*
Errors – 44 degrees of freedom	0.02	0.37	0.02	0.30
S.D.	0.15	0.61	0.15	0.55
Mean	0.47	0.82	0.47	0.76
C.V. (%)	32.5	74.0	32.1	72.7
Mean ratios				
RRIM 501	0.15	0.22	0.15	0.22
GT 1	0.47	0.69	0.48	0.71
RRIM 600	0.61	1.18	0.61	1.20
PB 86	0.56	1.11	0.57	0.73
Tjir 1	0.54	0.93	0.55	0.94
S.E. (±)	0.04	0.18	0.04	0.16
L.S.D. (P = 0.05)	0.13	0.50	0.13	0.46

***Significant at $P < 0.001$
**Significant at $P < 0.01$
*Significant at $P < 0.05$

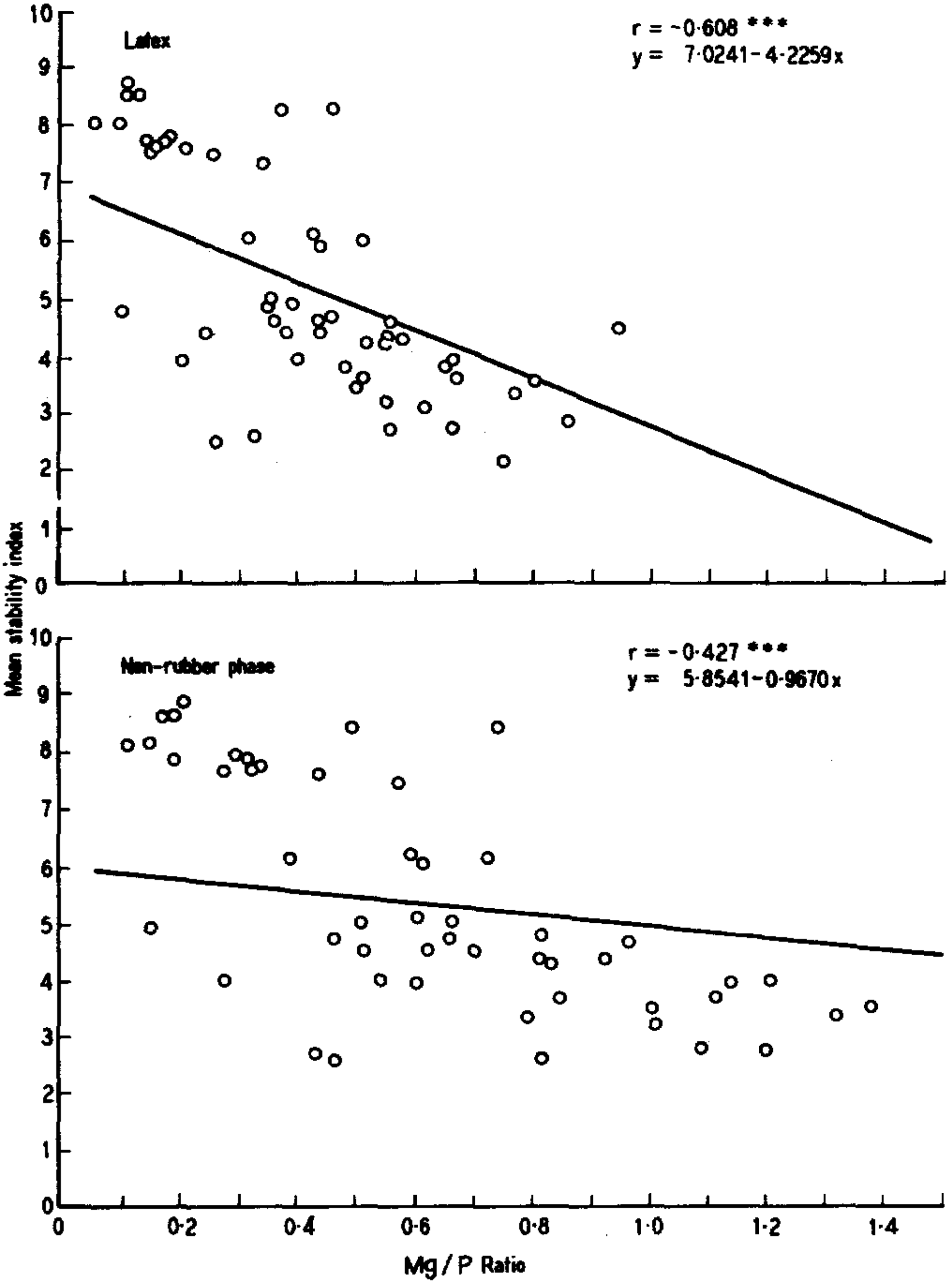

Figure 2. Correlation of mean stability indices of fresh latices and ratios of Mg/P for total phosphorus in whole latex and for phosphorus in the corresponding non-rubber phase.

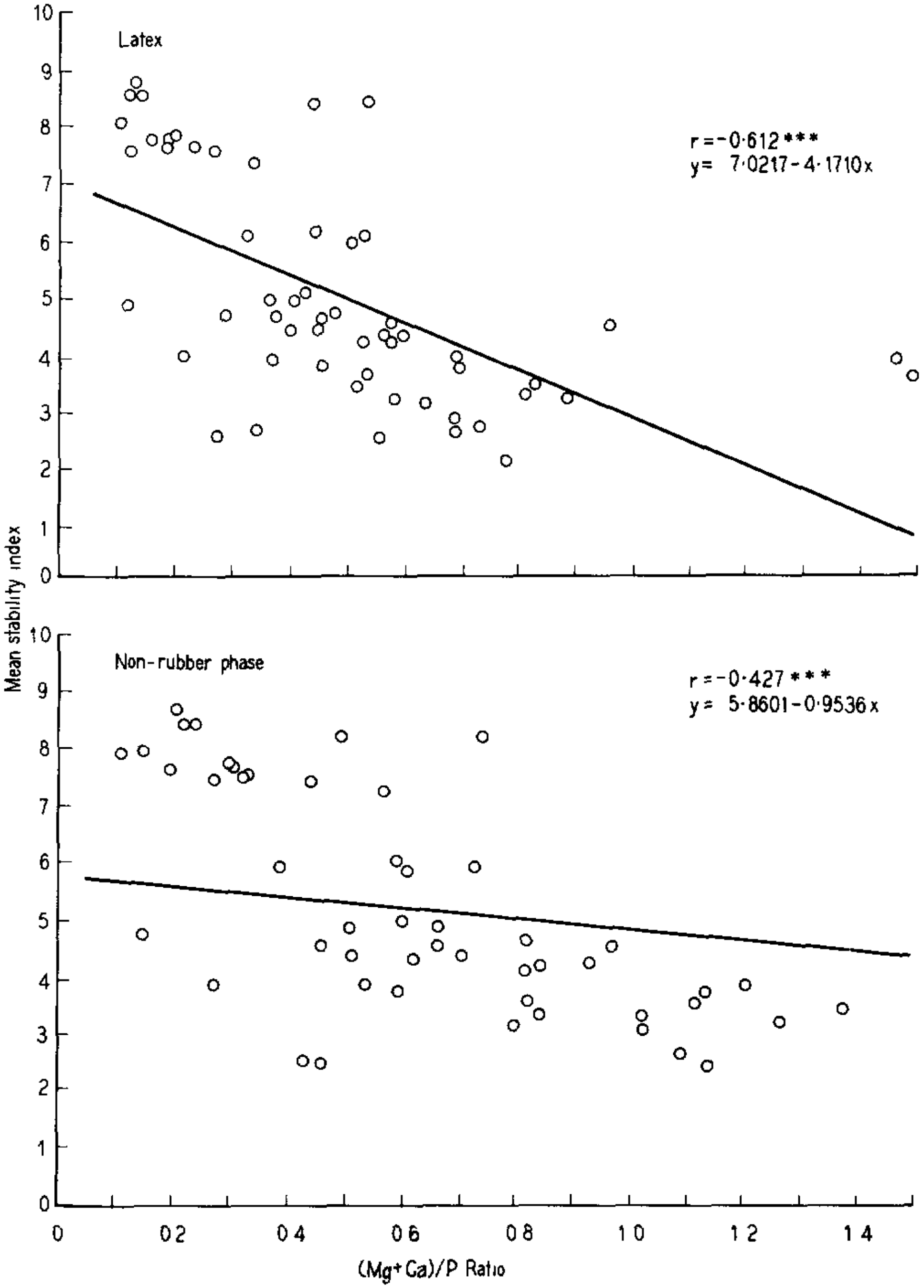

Figure 3. Correlation between the mean stability indices of fresh latices and ratios of (Mg + Ca)/P for total phosphorus in whole latex and for phosphorus in the corresponding non-rubber phase.

lower levels of calcium present in latex as compared to magnesium.

Relationship between Mean Stability Index and Plugging Index

Plugging index is a measure of the duration of latex flow: trees with long flow times have low plugging indices and trees with short flow times have high plugging indices. Preliminary observations reported earlier suggested a relationship between the mean stability index of latex and plugging index. To further investigate this, measurements of latex stability and plugging indices carried out with clones GT 1, PB 86, RRIM 501, RRIM 600 and Tjir 1, initially for three months[4], were extended to a period of twenty-five months. Results of mean stability indices and plugging indices expressed as monthly averages for each clone are shown in *Figures 4* and *5* respectively.

Clonal differences in both the parameters measured were apparent. Statistical analyses of the data were consistent with this observation *(Table 8)*. Although marked month-to-month variations for both the indices were also evident, the plugging index appeared to be a more variable parameter than the mean stability index, as revealed by the higher coefficient of variation of 34.9% for the former

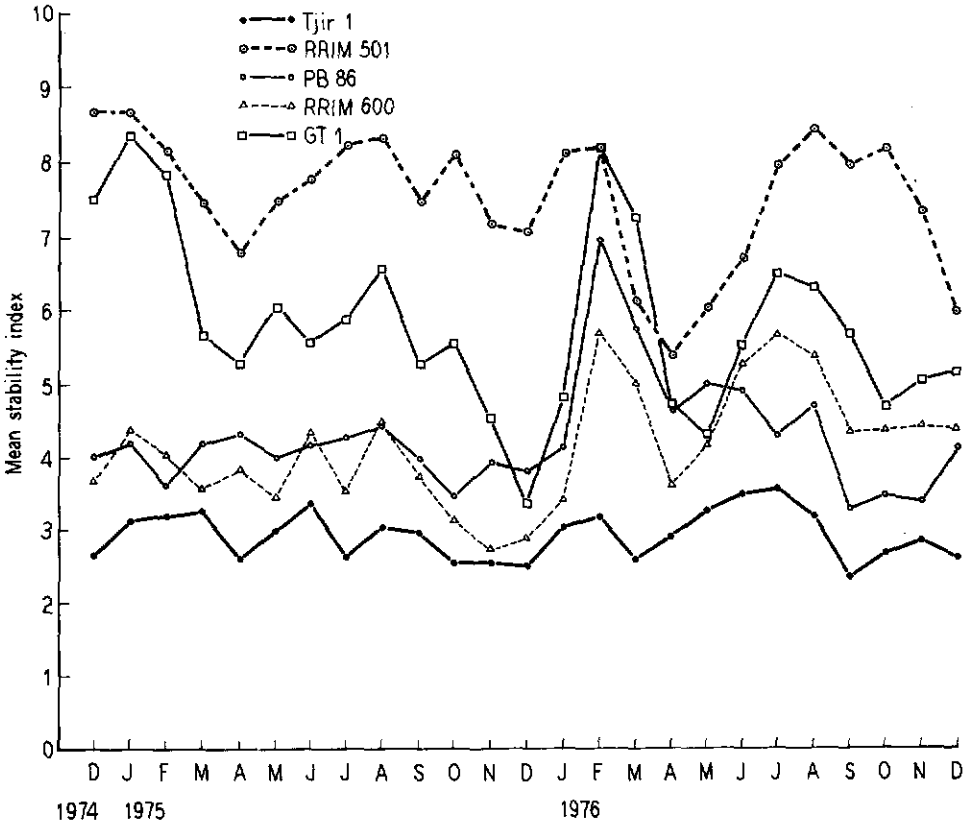

Figure 4. Month-to-month variation of mean stability indices of fresh latices from five clones in Field 14D.

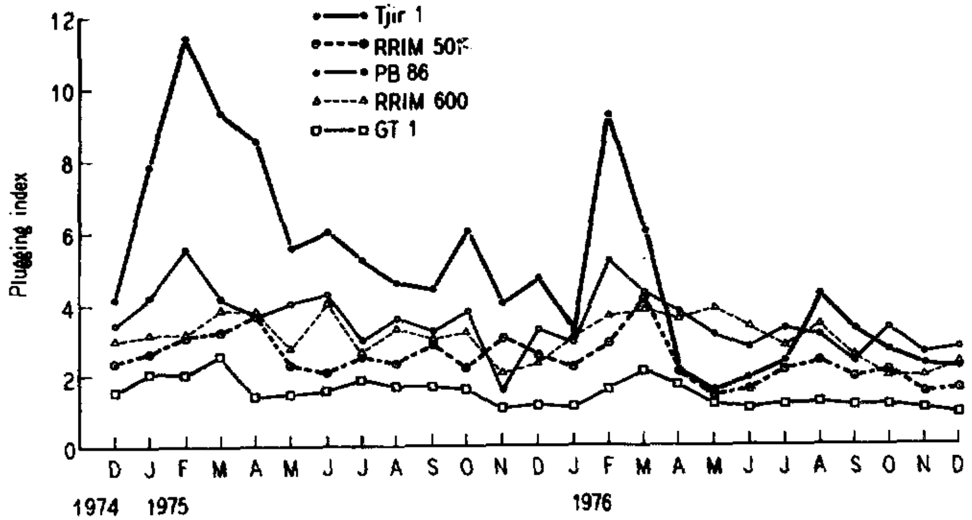

Figure 5. Monthly variation of plugging indices of five clones.

TABLE 8. ANALYSIS OF VARIANCE AND MEANS OF MEAN STABILITY AND PLUGGING INDICES OF FIVE CLONES

Item	Mean stability index	Plugging index
Mean squares		
Clones – 4 degrees of freedom	78.00***	41.94***
Months – 24 degrees of freedom	1.58***	4.09***
Errors – 96 degrees of freedom	0.55	1.19
S.D.	0.74	1.09
Mean	5.01	3.12
C.V. (%)	14.85	34.88
Mean		
Tjir 1	3.00	4.98
PB 86	4.34	3.56
RRIM 600	4.24	3.12
GT 1	5.89	1.50
RRIM 501	7.59	2.45
S.E. (±)	0.15	0.22
L.S.D.	0.42	0.61

***Significant at $P < 0.001$

compared to that of 14.9% for the latter. Except for clone RRIM 501 which showed the highest mean stability index and the lowest, but one, in plugging index, the two indices indicated an inverse relationship for all clones: that is, high plugging index was associated with low latex stability and low plugging index was associated with high latex stability. Statistical analysis of the data confirmed this relationship showing that these indices were highly correlated between clones (correlation coefficient = −0.450***, significant at $P < 0.001$).

Relationship between Aerosol OT Latex Stability, Plugging Index and Yield

It has been established that plugging index which is a measurement of the duration of latex flow, is inversely correlated to latex yield[6]. The mean stability index on the other hand, is not a direct measurement of the duration of flow, but shows an inverse relationship with the plugging index. It is therefore of interest to see if this index is in any way related to yield.

Latex yields of five clones were recorded over the same experimental period as the determinations of mean stability and plugging indices. Results are shown in *Table 9*. While there was correlation between plugging index and latex yield, as expected[6], both between clones and within clones (except for PB 86), such relationship was not observed between the mean stability index and yield.

Influence of Rainfall on Plugging and Mean Stability Indices

Rainfall recordings were taken over the experimental period of twenty-five months during which both the plugging index and the mean stability index were determined. Expressing all the three parameters as monthly averages, the data were examined. It was found that rainfall had no significant effect on either the plugging index or the mean stability index of the five clones as indicated by the correlation coefficients obtained for both cases *(Table 10)*.

TABLE 9. CORRELATION OF PLUGGING AND MEAN STABILITY INDICES WITH LATEX YIELD FOR FIVE CLONES

Clone	Correlation of yield with Plugging index	Correlation of yield with Mean stability index
Within clone		
Tjir 1	−0.871***	0.180 NS
PB 86	−0.249 NS	−0.427*
RRIM 600	−0.584**	−0.131 NS
GT 1	−0.578**	0.109 NS
RRIM 501	−0.718***	0.188 NS
Between clones	−0.610***	0.152 NS

*** Significant at $P < 0.001$
** Significant at $P < 0.01$
* Significant at $P < 0.05$
NS= Not significant

TABLE 10. CORRELATION BETWEEN RAINFALL AND PLUGGING AND MEAN STABILITY INDICES OF FIVE CLONES

Clone	Correlation of monthly rainfall with	
	Plugging index	Mean stability index
Within clone		
Tjir 1	−0.072 NS	−0.342[a]
PB 86	−0.045 NS	−0.120 NS
RRIM 600	−0.076 NS	−0.143 NS
GT 1	0.013 NS	−0.164 NS
RRIM 501	−0.072 NS	−0.198 NS
Between clones	−0.030 NS	−0.113 NS

[a]Significant at $P < 0.10$
NS = Not significant

An effect of rainfall on plugging index was suggested as reported earlier[12]. It should however be noted that the data concerned, obtained over a period of one year, had not been statistically analysed.

Effects of Yield Stimulation

The mean stability and plugging indices and latex yields of stimulated and unstimulated trees of each of the five clones were followed through a pretreatment and thirteen treatment (with ethephon) periods at two-monthly intervals. Expressing the data obtained as mean values per two-month period, results were compared between the control and stimulated trees, as shown in *Figure 6* for latex stability, *Figure 7* for plugging index and *Figure 8* for latex yield. Application of ethephon to the trees produced no consistent effects on the mean stability indices of the latices obtained, though it gave rise to marked lowering generally of the plugging indices, as expected[13,14], throughout the experiment *(Table 11)*. The reduced plugging indices may be explained by the prolonged flow time resulting from stimulation[6,13,15]. Positive responses in latex yield were initially observed in all the clones investigated. They however disappeared in the case of the more stable clones of RRIM 501 and GT 1 after the ninth treatment and RRIM 600 after the twelfth treatment. Negative yield responses were in fact shown by these trees during and after these periods. It is interesting to note that inspite of the low latex yields of these stimulated trees during these periods of negative response, their plugging indices remained at the reduced levels initially observed when they were first stimulated. While the major effect of yield stimulants in increasing yields has been shown to prolong latex flow by delaying latex vessel plugging, the present observation implies that yield response to stimulation involves other factors besides vessel plugging.

DISCUSSION

It is generally recognised that the negatively charged complex surface layer of the rubber hydrocarbon particles, consist-

TABLE 11. MEANS OF PLUGGING AND MEAN STABILITY INDICES OF STIMULATED AND UNSTIMULATED TREES FOR FIVE CLONES

Clone	Mean stability index			Plugging index		
	Control	Stimulated		Control	Stimulated	
Tjir 1	3.01	3.28	S.E.	4.98	1.87	S.E.
PB 86	4.34	4.63	±0.15	3.56	1.68	±0.17
RRIM 600	4.24	4.02		3.12	1.28	
GT 1	5.89	4.81	L.S.D.	1.50	0.83	L.S.D.
RRIM 501	7.59	7.87	0.43	2.45	1.07	0.48
S.E. (±)	0.15	0.12		0.22	0.08	
L.S.D.	0.42	0.32		0.61	0.21	

ing of proteins and lipids[16,17,18] contribute to the colloidal stability of the latex system. Measurements of surface area of this layer of particles from five clones showing marked differences in their latex stabilities however, did not indicate any relationship with the latter. This lack of correlation may be largely attributed to the absence of significant differences in the surface area between clones, as is evident in *Table 1*. The influence of rubber particles on stability of clonal latices may on the other hand, be reflected by differences in their surface charges. This aspect is being investigated.

Lutoid particles which enclose within them a potential destabiliser consisting of mainly cationic materials including the divalent cations, magnesium and calcium, have been shown to contain a large proportion of the total magnesium and total calcium in latex[10]. These two cations are known to destabilise latex particles when present in sufficient quantities[19]. Hence, higher concentration of these cations in lutoids would increase the destabilising power of their serum and would thus give rise to greater instability in the latex system when lutoids are damaged, particularly during flow. Although some magnesium and calcium are also present in the ambient C-serum, but owing to the inadequate amount and the presence of counter ions, notably phosphates, these cations by themselves are not likely to cause any destabilisation of the latex particles. They may however have an additive effect on that of the lutoid serum cations when released. The present study of the magnesium levels in the lutoid serum, lutoid particles and the non-rubber phase (lutoids + C-serum) of fresh clonal latices with different stabilities has revealed that there are marked differences between clones in all cases. In addition, a statistically significant inverse relationship between the magnesium contents and latex stability has been obtained, that is, clonal latices with low magnesium levels exhibit high latex stabilities and clonal latices with high magnesium contents indicate low latex stabilities. Such a relationship, on the other hand, was not observed in the case of calcium, although clonal variation was significant. In any case, the influence of calcium content on latex stability, if any, would be expected to be comparatively

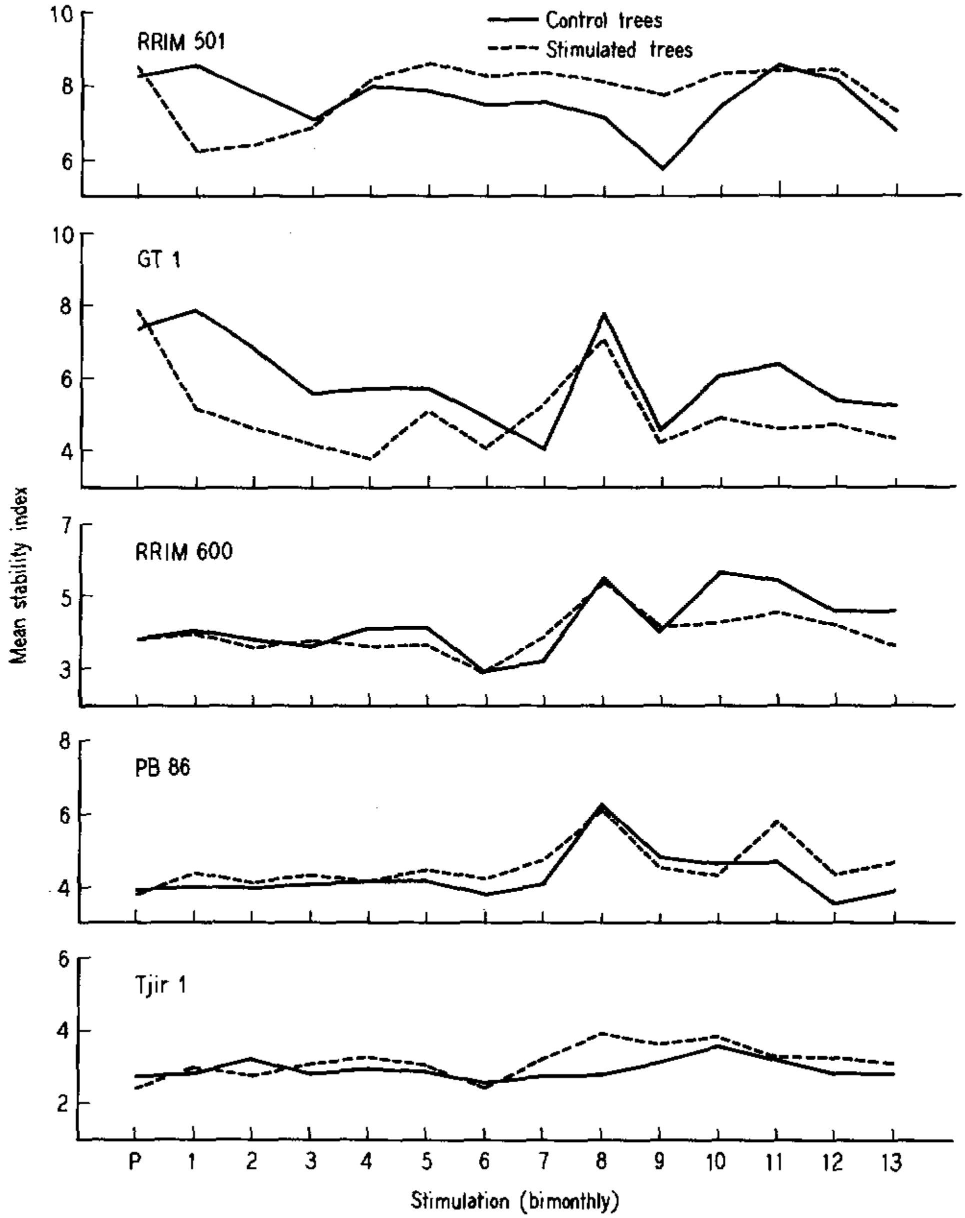

Figure 6. Effects of ethephon stimulation on mean stability indices of five clones in Field 14D, over one pretreatment (P) and thirteen stimulation periods of two months each.

less than that of magnesium, due to its very much lower level in latex.

Phosphorus is present in fresh latex mainly as inorganic phosphates in the

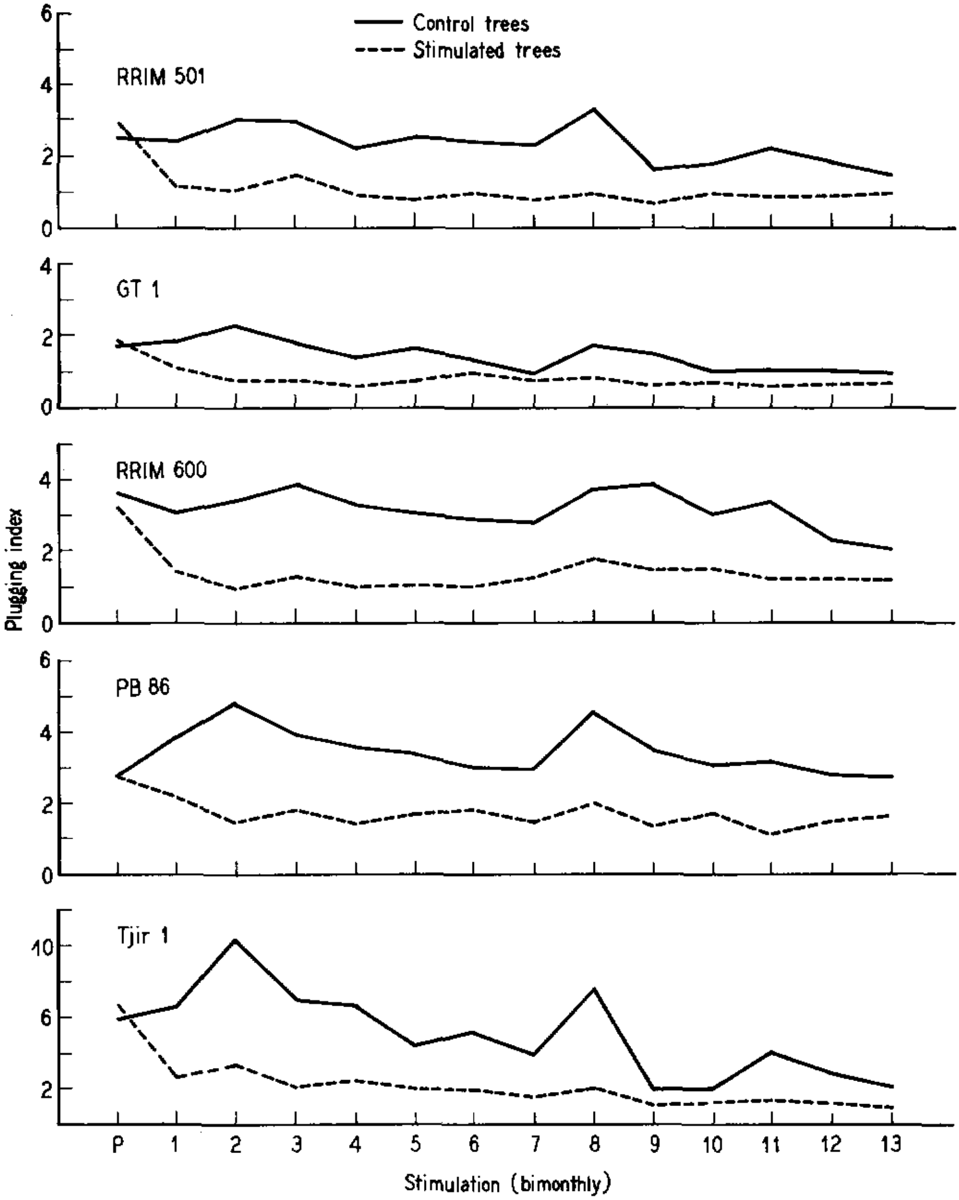

Figure 7. Effects of ethephon stimulation on plugging indices of five clones over one pretreatment (P) and thirteen treatment periods.

serum phase[5,20], especially in C-serum[11] and as phospholipids in the rubber phase[5,16,18], and in the lutoid membrane[21] In view of the possible role that phosphate ions might play in counter-acting the electrostatic interactions between the lutoid serum and rubber particles, as well as the destabilising action of the Aerosol OT on fresh latex, the presence of phosphorus in latex is thought to contribute a

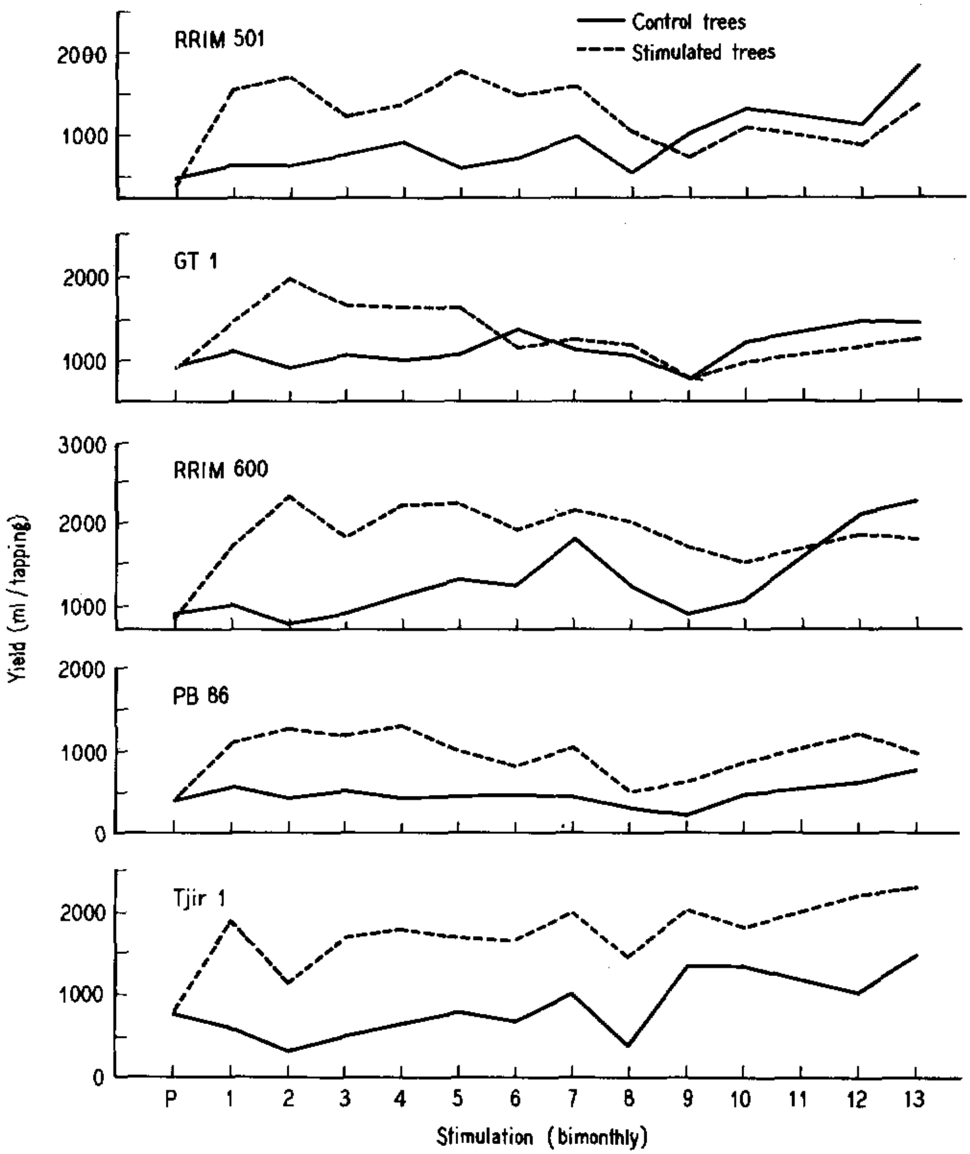

Figure 8. Yield responses to ethephon stimulation for five clones in Field 14D over one pretreatment (P) and thirteen treatment periods.

stabilising effect on the latex system. Consequently, higher levels of phosphorus in latex are believed to favour higher latex stabilities. Investigations on the phosphorus contents of fresh latices showed that they varied between clones and that higher contents were found in clonal latices with higher latex stabilities, while lower levels were detected in clonal latices of lower stabilities, in all the clones studied except for Tjir 1. This finding reflects somewhat strongly the influence of phosphorus as a factor favouring latex stability. A positive correlation between the latex phosphorus levels and latex stability has indeed been observed for the various clones investigated. An unexpectedly high phosphorus content was observed in clone Tjir 1 in view of its low latex stability, suggesting that the influence of other factors was more important in this case.

As divalent magnesium and calcium ions are capable of destabilising latex particles and phosphorus, particularly in the form of phosphate ions, is likely to enhance latex stability, their antagonistic effect was studied in terms of their ratios, that is, magnesium or magnesium and calcium (available in B and C sera) to total phosphorus in whole latex or in non-rubber phase. Results obtained showed not only significant clonal differences in the parameters examined, but also an inverse relationship between these ratios and latex stabilities. It may therefore be inferred that clonal variation in latex stability is governed to a certain extent by differences in their inherent latex properties such as those reported in this work. While other inherent properties like the resistance of lutoid membrane to damage may also constitute further factors determining the differences in stability between clonal latices, its influence, while probably important, has not yet been established.

In the studies of latex vessel plugging leading to cessation of latex flow, the influence of latex stability has often been implicated. The confirmation of the inverse correlation observed earlier[4] between latex stability and plugging index of different clones is an indication of this: high plugging clones are associated with low latex stability and *vice versa*. However, although plugging index has been shown to be interrelated to latex yield of the trees and their response to yield stimulation, such relationships have not been established with the latex stability index. This may be explained by the fact that variation in latex yield between clones is determined by, not only plugging index, but also other aspects of clonal behaviour. Rainfall did not have any significant effect on either the plugging index or the latex stability measured.

The present study, though based on a limited number of clones, has provided some useful information on the stability of fresh unammoniated clonal latices which is otherwise not available. It relates the clonal variation in latex stability to certain intrinsic differences between clonal latices such as the effects of their cations and counter-ions. Such investigations when extended to study the influence of mineral deficiencies in plantations may prove beneficial to the discrimatory application of fertilisers, where $(Mg + Ca)/P$ ratios influence latex vessel plugging.

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Rubber Research Institute of Malaysia
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