Indian Journal of Natural Rubber Research, **13**(1&2) : 69-78, 2000

VARIATION AND TREND OF YIELD AND RELATED TRAITS OF *HEVEA BRASILIENSIS* MUELL. ARG. IN TRIPURA

K.K.Vinod, Jacob Pothen, D.Chaudhuri, P.M.Priyadarshan, Thomas Eappen, Mary Varghese, Debasis Mandal, A.C. Sharma, Tapan Kumar Pal, A.S. Devakumar and A.K. Krishnakumar

Vinod, K.K., Pothen, J., Chaudhuri, D., Priyadarshan, P.M., Eappen, T., Varghese, M., Mandal, D., Sharma, A.C., Pal, T.K., Devakumar, A.S. and Krishnakumar, A.K. (2000). Variation and trend of yield and related traits of *Hevea brasiliensis* Muell. Arg. in Tripura. *Indian Journal of Natural Rubber Research*, **13**(1&2) : 69-78.

A study was undertaken to assess the variation and covariation of yield and related traits of ten clones of *Hevea brasiliensis*, during the peak yielding season for two years in Tripura, North East India. Initial flow rate (IF), plugging index (PI), dry rubber content (DRC), total solids content (TSC), inorganic phosphorus (P_i), sucrose content (SC), total volume of latex (TV) and dry rubber yield (RY) exhibited considerable seasonal and clonal variation. The response patterns of different traits varied from linear (IF, DRC, TSC and SC) to non-linear (PI, P_i, TV and RY). The patterns were similar during both the years under study. TV was found to be the major factor contributing to seasonal fluctuations in the dry rubber yield. DRC and TSC were found negatively associated with P_i and SC as observed in stimulated trees. SC was found to be the major determining factor of TV. P_i influenced TV positively through SC, while IF and DRC influenced TV negatively through SC. It appeared that the trees experience some kind of stimulation during the peak yielding season, causing increased laticifer activity and higher sucrose loading resulting in drainage of excess unutilized sucrose through latex serum. The phenomenon also causes prolongation of latex flow. Influence of wintering process and low temperature in determining the yield was evident.

Key words: *Hevea brasiliensis*, Non-traditional region, Path coefficient, Tripura, Yield.

K.K. Vinod (for correspondence), Hevea Breeding Sub-Station, Rubber Research Institute of India, Kadaba – 574 221, Karnataka, India; Jacob Pothen, Mary Varghese, Central Experiment Station, Chethackal, Kerala, India (E-mail : rrii@vsnl.com); D. Chaudhuri, P.M. Priyadarshan, Thomas Eappen, Debasis Mandal, A.C. Sharma, Tapan Kumar Pal, Rubber Research Institute of India, North East Research Complex, Agartala-799 006, Tripura, India; A.S. Devakumar, Forestry College, Ponnampetta, Karnataka and A.K Krishnakumar, Rubber Board, Kottayam-686 002, Kerala, India.

INTRODUCTION

Latex, the yield from rubber trees (*Hevea brasiliensis*) is produced in specialized cells called laticifers in the bark of the tree. The yield is primarily controlled by factors that influence latex production and latex flow. Genetic, environmental and physiological factors are known to influence these two phases of latex yield (Jacob *et al.*, 1989). The degree of influence of these factors on different components varies, thereby changing the overall response in terms of the dry rubber production. Besides, the trees yield throughout the year, incorporating wider seasonal fluctuations in the production pattern, which are typical to different agroclimatic zones.

The rubber tree being a relatively recent introduction to Tripura in North East India, which has a non-conventional environment for growing rubber, any study of the production pattern of clones in this region assumes prominence. The general trend of rubber yield in Tripura shows a sudden rise in latex volume from early October, which reaches a peak in mid-November and falls to the original level towards the end of January. The remaining part of the year is devoid of wide fluctuations. About 60 per cent of the annual rubber yield is obtained during this short period (Vinod *et al.*, 1996). This general trend in yield over the months remains the same for all clones, irrespective of their yield potential.

An attempt was made to study the variation and covariation among traits linked with latex flow, production and climatic factors with a view to understand their role in describing the dry rubber yield in the peak yielding season for two consecutive years.

MATERIALS AND METHODS

The study was undertaken in a clone evaluation garden comprising of fifteen oriental clones, planted during 1979, at the Regional Research Farm of Rubber Research Institute of India at Taranagar, Agartala, India (Location: 91° 15' E; 23° 53'N; 30m above msl). Ten clones consisting of high, medium and low yielders namely, RRII 105, RRII 118, RRII 203, RRIM 600, PB 235, PB 86, RRIC 105, GT1, Gl 1 and Harbel 1 were used in the study. Ten trees per clone having similar growth and yield were randomly selected from two blocks in the field trial. The yield as dry rubber (RY) and related characters of which four are linked with latex production *viz.*, dry rubber content (DRC), total solids content (TSC), inorganic phosphorus (P_i) (Taussky and Shorr, 1953) and sucrose content (SC) (Tupy, 1973) and three with latex flow *viz.*, rate of initial flow for first five minutes after tapping (IF), total latex volume (TV) and plugging index (PI) (Milford *et al.*, 1969) were recorded. The data were collected at weekly intervals throughout the peak yielding season from early October to late January for two years (1993-'94 and 1994-'95). The period of observation was counted as number of days starting from the first day of tapping during the season. This period more or less coincided with the onset of winter when the plants experience low temperature stress and also with the annual defoliation (wintering) period.

The analysis of variance was performed individually for the two years, with respect to all the characters. The determination of primary yield contributing traits and their sub-components was carried out using correlation analysis on two sets of data derived, one by pooling the clones over the days, and the other by pooling days over the clones. Since the present study was to understand the seasonal fluctuation, the data set obtained by pooling of clones were used for further analysis. An attempt was also made to correlate the yield and related traits with the means of common weather parameters *viz.*, maximum air temperature (T_{max}), minimum air temperature (T_{min}), and relative humidity during morning at 0625 IST (RH_m) and afternoon at 1225 IST (RH_n).

Path analysis was performed to illustrate the true relationship of the individual traits with the resultant variable using the pooled data, as the years had not shown much variation in the pattern of individual traits. The traits, which had true independence only were included in the path analysis. The DRC being the measure of dry rubber, which is the ultimate yield, was included. The IF was selected as it represented latex flow owing to the release of turgor inside the laticiferous system on tapping. Two more traits SC and P_i were also selected, as they were known to play a major role in the latex production mechanism. The TV was selected as the depend-

Table 1. Analysis of variance for yield and related traits during peak yielding season

		1993 – 94		1994 – 95	
Trait	Source of variation	Mean squares	Variance ratio**	Mean squares	Variance ratio**
RY (g/tree/tap)	Clones	4202.97	4737.22	2573.45	3113.21
	Days	3823.14	4309.11	2281.75	2760.34
	Clone × Days	152.36	171.72	130.51	157.88
IF (ml)	Clones	277.63	321.14	289.16	338.98
	Days	140.84	162.91	129.15	151.40
	Clone × Days	7.59	8.78	6.74	7.90
DRC (%)	Clones	168.99	201.60	225.63	264.37
	Days	531.45	634.00	330.91	387.73
	Clone × Days	12.65	15.10	11.10	13.00
TSC (%)	Clones	175.73	200.70	165.03	229.10
	Days	511.01	583.63	342.30	475.20
	Clone × Days	18.46	21.08	17.68	24.54
PI	Clones	7.47	77.14	6.17	76.85
	Days	59.07	609.95	12.26	152.73
	Clone × Days	1.05	10.83	0.42	5.19
SC (mg/100g)	Clones	30.04	388.18	45.38	583.76
	Days	37.58	485.67	71.20	915.96
	Clone × Days	3.73	48.17	3.99	51.31
TV (ml)	Clones	56327.87	19187.50	51376.23	14370.01
	Days	37179.64	12664.85	22601.75	6321.74
	Clone × Days	2059.87	701.67	2044.89	571.96
P_i (mg/100g)	Clones	50301.61	14406.39	64124.67	18908.69
	Days	53096.68	15206.90	28715.05	8467.32
	Clone × Days	2835.07	811.96	1174.37	346.29

** All the values were significant at $P \leq 0.01$

ent variable as it showed wide variation in the peak yielding phase and it solely determined the ultimate rubber yield. The PI was excluded, because it is an index derived from IF and TV, not having any independent property. The TSC was also excluded, as its major component DRC was included to avoid ambiguity of using DRC twice. Rubber yield being a product of TV and DRC, was excluded. All the statistical analysis was done according to standard procedures (Gomez and Gomez, 1994; Singh and Chaudhury, 1977).

RESULTS AND DISCUSSION

The results of the variance analysis are presented in Table 1. For all the characters studied all the three major components of variation *viz.*, clones, days and clone × days showed significant variation. The pattern of variation of individual traits is presented with their best-fit functions (Figs. 1 & 2). It showed that the response of traits over the period varied from linear to non-linear. The best-fit curves showed similar pattern of response for the individual traits during both the years. A linear downward trend was shown by IF, DRC and TSC, while the pattern of SC was linear and upward. The patterns of PI, TV, P_i and RY were described by quadratic equations.

The correlation coefficients of individual traits are presented in Tables 2a and 2b. The degree of dependence of components showed variation in the two sets of data, due to the existence of significant clone and clone × days variation during different phases of the study period. Only two pairs of components, TV with RY and DRC with TSC showed consistent association in the two sets of analyses. Though RY is the product of TV and DRC (Sethuraj, 1981), the association of DRC with RY was not prominent in the peak yielding season because the fluctuation in RY was contributed significantly by the variation in TV. The degree of fluctuation in DRC was marginal compared to that of TV. The rubber particles form above 90 per cent of the TSC, which explains its high positive association with DRC.

The IF was found significantly and positively associated with DRC as well as TSC and negatively with P_i and SC among clones. The IF also was found falling during the season as days advanced. The amount of latex flowing out in the first five minutes of tapping depended on the internal turgor of the laticifers before tapping (Chandrashekar, 1994). The decline of IF over the period could be attributed to dropping of the turgor in the latex vessels probably caused by the senescence process and low temperature stress.

Though PI was derived from IF and TV, it had shown strong negative association with TV alone. This is because the index was entirely determined by the TV which had a higher magnitude when compared to the weak numerator in the equation *viz.*, the rate of initial flow (ml/minute). Moreover, the initial rate of flow had nothing to do with the final latex volume obtained, which was attributed only to longer flow time during the peak yielding season. Thus the index, PI almost failed in indicating the plugging phenomenon in the present study situation. The PI also had a strong negative association with SC, caused by the latter's strong positive correlation with TV.

The DRC and TSC were negatively correlated with P_i and SC. The negative

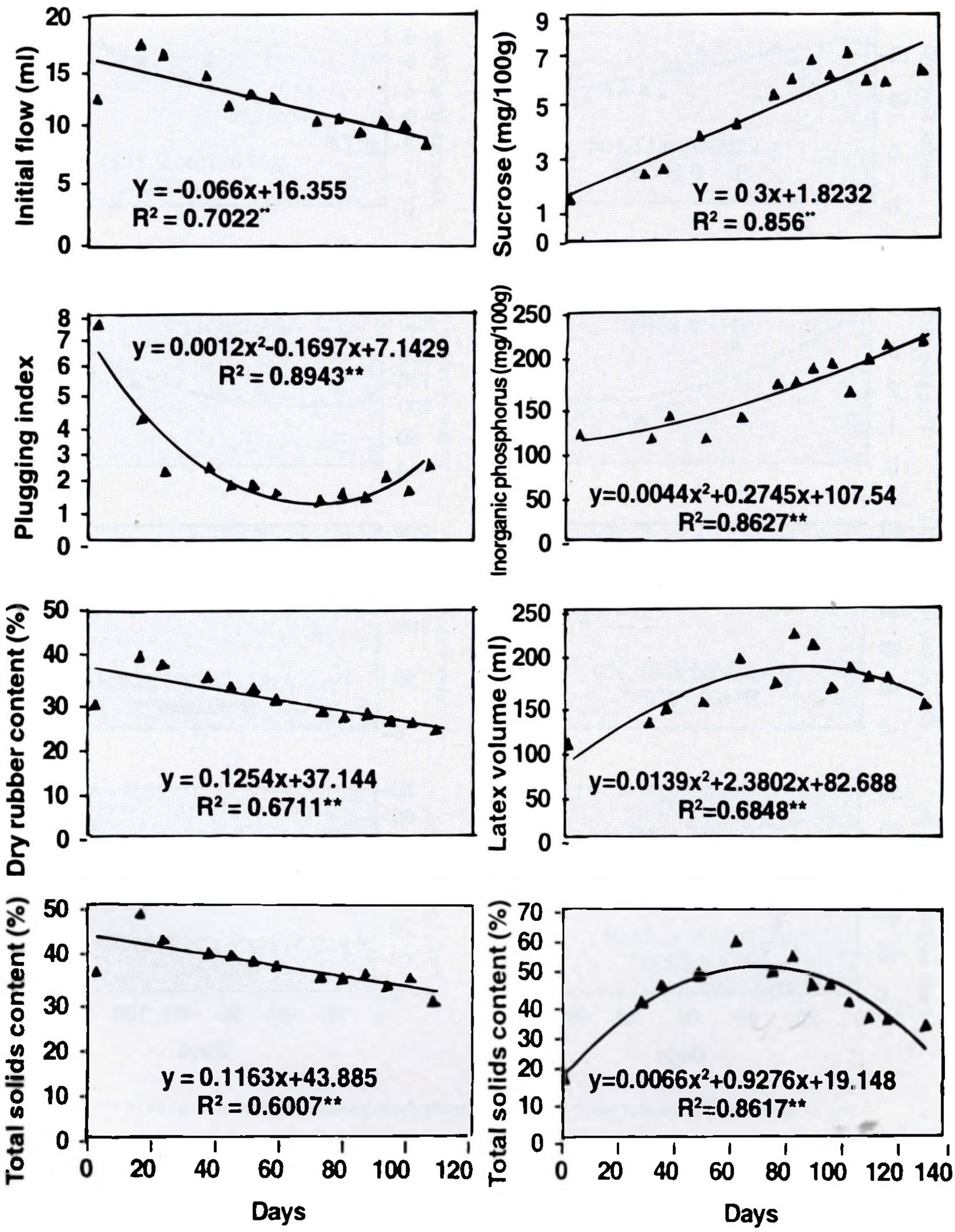

Fig.1. Response patterns of yield and related traits during the peak yielding season of 1993-94

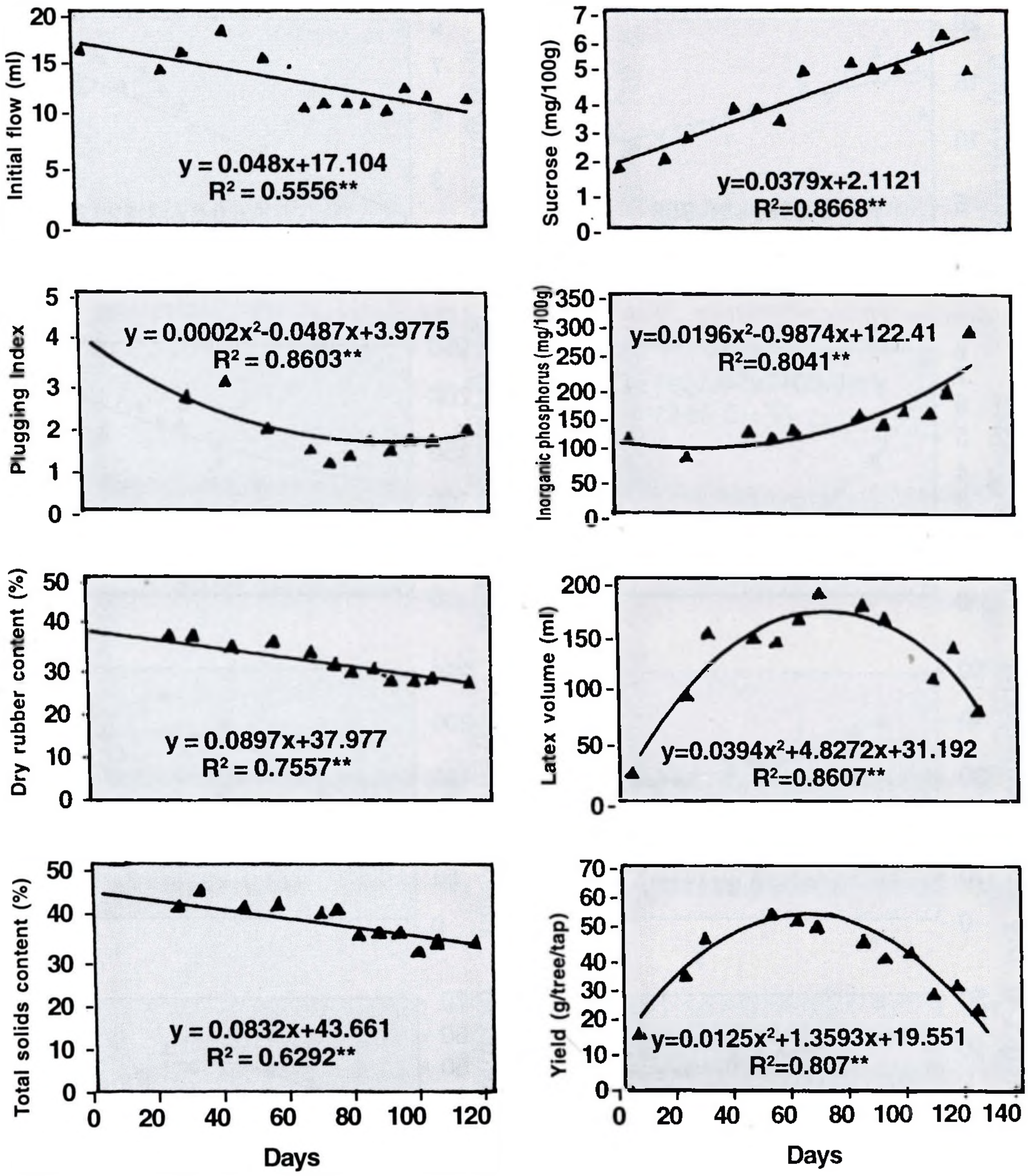

Fig.2. Response patterns of yield and related traits during the peak yielding season of 1994-95

Table 2(a). **Correlation coefficients of yield and related traits during 1993-94 season (upper diagonal) and 1994-95 season (lower diagonal) derived from pooled clone data**

	IF	PI	DRC	TSC	P_i	SC	TV	RY
IF	—	0.338	0.961**	0.939**	-0.788**	-0.762**	0.000	0.339
PI	0.827**	—	0.229	0.238	-0.281	-0.730**	-0.848**	-0.548
DRC	0.739**	0.639*	—	0.961**	-0.764**	-0.764**	0.083	0.481
TSC	0.613*	0.469	0.920**	—	-0.788**	-0.713**	0.060	0.379
P_i	-0.780**	-0.732**	-0.859**	-0.799**	—	0.630*	-0.160	-0.373
SC	-0.821**	-0.912**	-0.837**	-0.697*	0.812**	—	0.437	-0.004
TV	-0.536	-0.875**	-0.425	-0.201	0.438	0.740**	—	0.768**
RY	-0.025	-0.465	0.293	0.440	-0.119	0.245	0.631*	—

* Significant at $P \leq 0.05$ ** Significant at $P \leq 0.01$

relation of P_i and SC with DRC may be of greater relevance because it was noticed that the P_i and SC increased considerably throughout the peak yielding season, which coincides with the beginning of the wintering process while DRC had a steady fall. The P_i also had a strong positive association with SC. Such relationships are reported to be common in stimulated trees (Eschbach *et al.*, 1984; Lacrotte *et al.*, 1985).

Sugar, mainly as sucrose is the basic molecule of the laticiferous metabolism. It is the primary substrate in the isoprene synthesis, which leads to latex regeneration (Serres *et al.*, 1994). In the present study, the SC was found to increase while DRC and TSC had declined, but it had a positive association with TV especially during the 1994-95 season. This probably indicates the drainage of excess / unutilized sugar along with the latex serum (Prévôt *et al.*, 1984).

The pattern of weather parameters as mean weekly values for the study period is presented in Figure 3. The maximum temperature (T_{max}) and the minimum temperature (T_{min}) were found to drop and then climb. While the RH during morning (RH_m) was high and almost steady, that during afternoon (RH_n) fluctuated and fell. The simple linear relations of yield and

Table 2(b). **Correlation coefficients of yield and related traits during 1993-94 season (upper diagonal) and 1994-95 season (lower diagonal) derived from pooled season data**

	IF	PI	DRC	TSC	P_i	SC	TV	RY
IF	—	-0.073	0.067	-0.070	0.619*	-0.121	0.886**	0.882**
PI	-0.128	—	0.431	0.354	-0.168	-0.137	-0.467	-0.382
DRC	0.068	0.660*	—	0.902**	0.164	-0.754**	-0.171	0.039
TSC	0.196	0.589	0.974**	—	0.029	-0.771**	-0.233	-0.164
P_i	0.761**	-0.247	-0.009	0.109	—	-0.199	0.672*	0.674*
SC	-0.132	-0.213	-0.592	-0.560	-0.070	—	-0.040	-0.192
TV	0.858**	-0.596	-0.309	-0.152	0.703**	0.060	—	0.906**
RY	0.915**	-0.344	-0.050	0.042	0.800**	-0.095	0.876**	—

* Significant at $P \leq 0.05$ ** Significant at $P \leq 0.01$

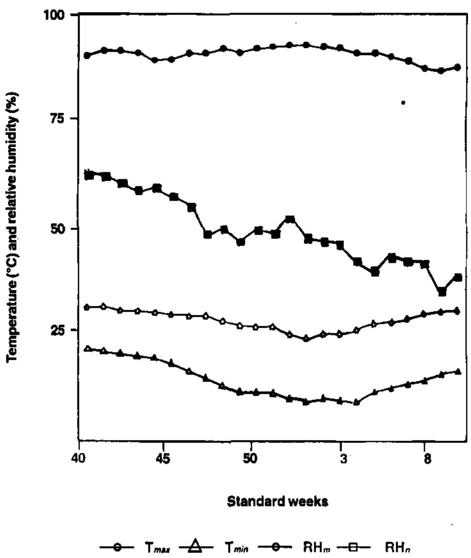

Fig.3. Mean weekly weather parameters of the peak yielding season (mean of ten years)

related variables with weather factors are presented in Table 3. The T_{max}, T_{min}, and RH_n had positive association with IF, PI, DRC and TSC, while the relation was strong and negative with P_i, SC and TV. The RH_m has shown a negative relation with IF and DRC.

Path analysis is a very useful technique as it generates insight on the related structures and cause-effect relationships which can be interpreted very easily (Sokel and Rolf, 1981). The result of path analysis is presented in Table 4. The direct effect or the path coefficient of the independent variable SC on TV was found significant, while other traits had no direct influence on the TV. However, P_i had a strong positive influence through SC. Similarly, IF and DRC had a strong negative influence on TV through SC. It is well known that P_i is involved in anabolic activity of the laticiferous system, especially in the isoprene synthesis, through adenosine phosphate and pyrophosphate bonds (Lynen, 1969). Hence, higher the P_i, higher would be the metabolic activity of the latex vessels. The sucrose level in the latex is dependent on two factors, its loading and *in situ* utilisation. The loading process involves very complex mechanism at the cell membrane level (Serres *et al.*, 1994). In the present study, with rise in SC and TV, and drop in DRC, it is logical to conclude that some stimulation activity is involved resulting in increase in sucrose loading, and lower *in situ* utilisation, resulting in drainage of unutilised sucrose through the latex serum. Moreover, the process also affects the plugging mechanism prolonging the latex flow. This phenomenon commonly known as late dripping is very common in many clones during peak yielding season. Since the path coefficient of the SC exceeded one, multicollinearity might have caused this

Table 3. **Simple linear correlation between important weather parameters with the yield and related traits during the peak yielding season.**

Weather parameter	Plant parameter							
	IF	PI	DRC	TSC	P_i	SC	TV	RY
T_{max}	0.784**	0.672**	0.797**	0.722**	-0.673*	-0.873**	-0.446*	0.025
T_{min}	0.830**	0.710**	0.811**	0.751**	-0.755*	-0.900**	-0.491*	-0.064
RH_m	-0.477*	-0.041	-0.497*	-0.363	0.219	0.280	0.033	-0.331
RH_n	0.723**	0.659**	0.694**	0.663**	-0.775*	-0.819**	-0.421*	-0.083

* Significant at $P \leq 0.05$ ** Significant at $P \leq 0.01$

Table 4. **Path coefficients (diagonal elements) and indirect effects of yield and related traits**

	IF	DRC	P_i	SC	Total 'r'	SE (path coeff.)
IF	**-0.089**	0.507	0.253	-0.816	-0.145	-0.681
DRC	-0.077	**0.587**	0.262	-0.822	-0.050	0.712
P_i	0.066	-0.453	**-0.339**	0.808	0.082	-0.551
SC	0.061	-0.407	-0.231	**1.184***	0.607	0.486

* Significant at $P \leq 0.05$; Residual effect = 0.5709; Coefficient of determination, R^2 = 0.6741

widely inflated value (Williams *et al.*, 1990). Moreover, the residual effect of 0.571 indicated that inclusion of more traits especially associated with latex flow and plugging mechanism might be required.

The mechanism of sudden jump in latex volume, prolonged flow, and latex dilution consistently occurring every year during peak yielding season in North East India, suggests that the trees experience a mechanism similar to stimulation, probably caused by lowering of temperature and the ongoing senescence process. The present study has revealed that the sucrose content plays a major role in yield determination. It also seems that there is a missing link between SC and TV. More detailed exploration during this phase, by including more biochemical traits related to sucrose metabolism, plugging mechanism, senescence process and low temperature stress would help in addressing the unexplored factors leading to more latex flow and dry rubber production.

REFERENCES

Chandrashekar, T.R. (1994). Correlation and path analysis of yield and its components, some factors of water relations and soil moisture in *Hevea brasiliensis*. *Indian Journal of Natural Rubber Research*, 7(2) : 89 – 94.

Eschbach, J.M., Roussel, D., Van de Sype, H. and Jacob, J.L. (1984). Relationships between yield and clonal physiological characteristics of latex from *Hevea brasiliensis*. *Physiologie Vegetale*, **22** : 295 – 304.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedures for agricultural research. John Wiley and Sons Inc., New York 680p.

Jacob, J.L., Prévôt, J.C., Roussel, D., Lacrotte, R., Serres, E., d'Auzac, J., Eschbach, J.M. and Omont, H. (1989). Yield limiting factors, latex physiological parameters, latex diagnosis, and clonal typology. In: *Physiology of Rubber Tree Latex*. (Eds. J. d'Auzac, J.L Jacob and H. Chrestin). CRC Press Inc., Florida, pp. 345–382.

Lacrotte, R., Van de Sype, H., and Chrestin, H. (1985). Influence de l'ethylene sur l'utilisation du saccharose exogene par les laticiferes d'*Hevea brasiliensis*.: Proposition d'une mecanisme d'action. *Physiologie Vegetale*. **23** : 187–198.

Lynen, F. (1969). Biochemical problems of rubber synthesis. *Journal of the Rubber Research Institute of Malaya*, **21** : 851 – 853.

Milford, G.F.J., Paardekooper, E.C. and Yee, H.C. (1969). Latex vessel plugging, its importance to yield and clonal behaviour. *Journal of the Rubber Research Institute of Malaya*, **21** : 274–282.

Prévôt, J.C., Jacob, J.L. and Vidal, A. (1984). Le potential d'oxydorédection: Etude de sa signification physiologique dans le latex de l' *Hevea brasiliensis*. Son utilisation comme critère physiologique. Rapport 2/84, Institut Recherches de la Caoutchouc, CIRAD, Montpellier, France.

Serres, E., Lacrotte, R., Prévôt, J.C., Clement, A., Commere, J. and Jacob, J.L. (1994). Metabolic aspects of latex regeneration *in situ* for three *Hevea* clones. *Indian Journal of Natural Rubber Research*, 7(2) : 79–88.

Sethuraj, M.R. (1981). Yield components in *Hevea brasiliensis* : Theoretical considerations. *Plant, Cell and Environment*. **4** : 81–83.

Singh, R.K. and Chaudhury, B.D. (1977). Biometrical methods in quantitative genetic analysis. Kalyani Publishers, New Delhi.

Sokel, R.R. and Rohlf, F.J. (1981). Biometry. Ed.2. W.H. Freeman & Co., New York.

Taussky, H.H. and Shorr, E. (1953). A microcalorimetric method for the determination of inorganic phosphorus. *Journal of Biological Chemistry*, **202** : 675–685.

Tupy, J. (1973). The level and distribution pattern of latex sucrose of *Hevea brasiliensis* Muell. Arg. as affected by the sink region induced by latex tapping. *Physiologie Vegetale*, **11** : 1–11.

Vinod, K.K., Meenattoor, J.R., Priyadarshan, P.M., Pothen, J., Chaudhuri, D., Krishnakumar, A.K., Sethuraj, M.R. and Potty, S.N. (1996). Early performance of some clones of *Hevea brasiliensis* in Tripura. *Indian Journal of Natural Rubber Research*, **9**(2) : 123–129.

Williams, W.A., Jones, M.B. and Demment, M.W. (1990). A concise table for path analysis statistics. *Agronomy Journal*, **82** : 1022–1024.