Proceedings of Placrosym XV (2002): 348-355

EFFECT OF ALTITUDE ON RUBBER YIELD AND ITS COMPONENTS OF SOME *HEVEA* CLONES UNDER TWO AGROECOREGIONS OF INDIA

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ABSTRACT

The study was conducted in five *Hevea* clones (RRII 105, RRII 118, RRII 203, RRIM 600, and PB 235) planted in 1985 and laid out in a completely randomised block design with 50 replications each at Sorutari Farm (Lat.: 26°.35'N, Long: 90°52'E, altitude 50 to 105 m above MSL) under Kamrup district of Assam and at Ganolgre farm, Tura, West Garo Hills, Meghalaya (Lat: 26°26'N, Long: 90°91'E, altitude 600 m above MSL) under two agroecoregions No: 15 and 17 respectively. The genotypic variation of the clones interacted with the environmental factors, variability of which is pronounced in altitudes and months of the year. Altitude had significant correlation with dry rubber content, rubber yield, latex yield while rubber yield showed significant correlation with latex yield and plugging index respectively. The relationship between dry rubber content and girth increment was highly significant. Plugging index was significantly correlated with latex yield.

The suitability of initial and final models with regard to each clone for prediction of rubber yield is confirmed by the significance of regression indices which was evident by the lesser value of residual sum of squares than that of regression sum of squares and high significance of the F statistics. Moreover in each case the regression coefficients being nearly 1 are also indicative of the fitness of the model.

In case of all the clones the initial models appeared to give better prediction of a yield-yield component and environment model as was observed by the higher value of realized multiple regression coefficients. Nevertheless, the final model determined that altitude was a deciding factor towards rubber yield in case of only clones RRII 105, RRII 118 and RRIM 600 while for the clones RRII 203 and PB 235, the effect of altitude was almost negligible.

INTRODUCTION

Hevea brasiliensis, the para rubber, original source and inspiration for an entire industry and countless products indispensable to modern society, is comparatively a new entrant to the north-eastern India, which has a non conventional environment for cultivation of rubber. The yield of rubber is predominantly controlled by the factors that influence production as well as flow of latex. 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 dry rubber yield. Besides, the trees yield throughout the year, undergoing an array of seasonal fluctuations in the production pattern, which are typical to different agro climatic zone (Vinod *et al.*, 2000). Yield being a complex trait; all variations in yield are the integrated effect of the variation occurring in the component traits (Chandrasekhar, 1994). Clonal variation too greatly influences the yield and yield components (Vinod, 2001). Elevation affected rubber productivity through its significant and positive correlation with mean annual rainy days (Darmandono, 1996).Though multiple regression on rubber yield-climatic variability was reported (Rao *et. al.*, 1998), the yield variability and its association with altitude and months in non-traditional rubber growing areas have not been reported so far. Hence, an attempt has been made to investigate the yield-altitude relationships in rubber under two different agro- ecoregions of India.

The objectives of the present study focused at:

i) Estimation of the degree of association between variability in monthly rubber yield and yield components of five different clones raised to the yielding stage at two varied altitudes.

ii) Developing a clone specific relationship between rubber yield as criterion variable and yield components during different months along with altitudes as predictors, followed by the identification of the best predictor.

MATERIALS AND METHODS

The study was conducted in five Hevea clones (RRII 105, RRII 118, RRII 203, RRIM 600, and PB 235) coded as 1,2,3,4 and 5 planted in 1985 and laid out in a completely randomised block design with 50 replications each at Sorutari Farm (Lat.: 26^0.35′N, Long: 90^{0}52′E, altitude 50 to 105 m above MSL) under Kamrup district of Assam and at Ganolgre farm, Tura, West Garo Hills, Meghalaya (Lat: 26^{0}26′N, Long: 90^{0}91′E, altitude 600 m above MSL) under two Regional Research Stations of the Rubber Research institute of India. Parameters studied are tabulated in table-1. The study sites fall under the agro-ecoregion 17 (Ganolgre) and 15 (Sorutari) defined as altitude-1 and 2 respectively (Sehgal et al., 1992) as shown in Fig.-1. Data on different agro meteorological parameters were recorded periodically from the observatories situated near the plantation at Sorutari and Ganolgre farm respectively. The trees were opened for tapping in 1994 at Sorutari and 1995 at Ganolgre respectively. At both the locations the trees were exploited under 1/2 S d/2 system. Yield (RY) was recorded three times in a month by cup coagulation method and dry rubber content (DRC) was recorded at fortnightly intervals by adopting standard procedure. Latex yield (LY) and plugging index (PI) were recorded by following the method of Milford et al., (1969) and girth increment (GI) was also recorded at monthly intervals for three consecutive years after opening. Clone wise monthly mean data on yield and yield components over the first three years of tapping were computed. Summary statistics were carried out for rubber yield and four yield components such as dry rubber content, plugging index, latex yield and girth increment. Pearson correlation coefficients were calculated between the yield, yield components and altitude. Finally multiple backward regression was worked out for the data of each clone to derive the relationship and contribution of environmental factors such as altitude and month and four yield components towards the expression of rubber yield. All the analyses were performed following Gomez and Gomez (1984) after pooling monthly mean values recorded for five clones.

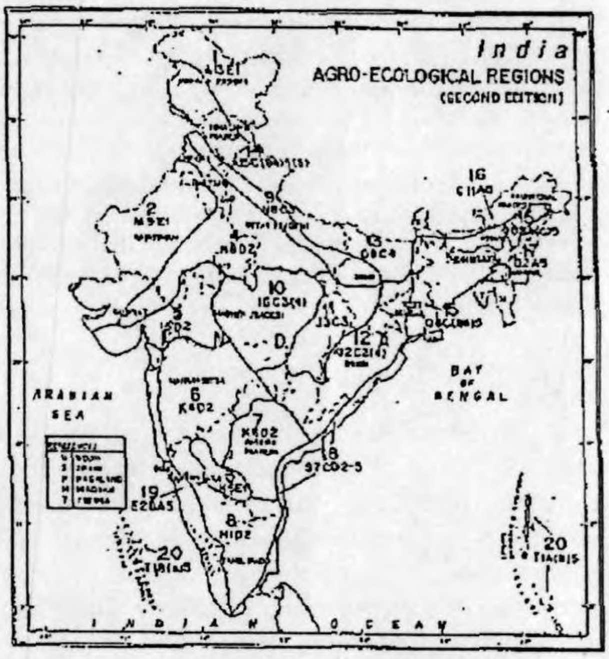

Fig. 1. Agro-ecological regions of India

Table 1. Parameters Scored for Statistical Analysis

Parameter	Abbreviation	Unit	Remarks
Yield	Rubber Yield	RY g/tree/tap	RY_1.....RY_5 = Rubber Yield of clone 1...5
Yield components	Dry Rubber Content	DRC (%)	$DRC_{1...}DRC_5$= Dry Rubber Content of clone 1...5
Plugging Index		PI	PI_1....PI_5= Plugging Index of clone 1...5
Latex yield		LY ml/tree/tap	$LY_{1...}LY_5$ =Latex Yield of clone1...5
Girth Increment		GI cm	GI_1...GI_5 = Girth Increment of clone 1...5
Environment	ALT	Meter	(above MSL)
ALT_1=600	ALT_2=105	MONTH	Jan.- Dec=1...12

RESULTS AND DISCUSSION

Description of Summary Statistics

Table 2 reveals that the rubber yield ranged from 2.60 to 29.97 g/tree/tap and was highest in the clone RRIM 600 (29.97±2.63) and minimum in RRII 203(2.60±1.92). Dry rubber content ranged from 20.01 to 42.60 per cent. Maximum dry rubber content was recorded in the clone RRII 203 (42.60±4.46 and minimum in PB 235 (20.31±20.09). Plugging index was highest in PB 235 (7.61±0.49) and lowest in the clone RRII 203 (1.17±0.36). The latex yield ranged from 10.46 to 99.26 ml/tree/tap. Latex yield was maximum in clone RRIM 600 (99.26±8.00) and minimum in RRII 105 (10.46±8.56). Girth increment was recorded maximum in RRII 118 (0.88±0.08) and minimum in RRII 105 (0.01±0.05). It is evident from the summary statistics that genotypic variation of the clones interacted with the environmental factors, variability of which is pronounced in altitudes and months of the year. Thus varied physiological responses led to a widely varied yield attributes. Climatic variation during different months of the experimental period is graphically presented in Fig- 2 and 3.

Description of Correlation Coefficients

Association among the factors studied as indicated by the correlation coefficients are

Table 2. Summary Statistics of Rubber Yield and its Components at Varied Altitude

Yield and yield components	Clone	Mean	SE	SD	Minimum	Maximum
	RRII 105	14.68	2.46	8.54	3.91	26.65
	RRII 118	16.06	2.46	8.51	5.08	27.06
Rubber yield	*RRII 203*	10.74	1.92	6.64	2.60	22.10
	RRIM 600	17.08	2.63	9.10	5.59	29.97
	PB 235	13.10	2.26	7.82	3.50	26.81
	RRII 105	35.27	1.49	5.17	27.60	42.50
	RRII 118	33.24	1.28	4.43	26.82	39.95
Dry rubber content	*RRII 203*	34.32	1.29	4.46	27.54	42.60
	RRIM 600	35.54	1.28	4.42	29.12	42.10
	PB 235	32.40	2.09	7.24	20.31	38.30
	RRII 105	3.68	0.40	1.40	1.50	6.18
	RRII 118	3.43	0.36	1.26	1.53	5.14
Plugging index	RRII 203	2.72	0.36	1.26	1.17	5.03
	RRIM 600	3.79	0.45	1.55	1.80	6.05
	PB 235	3.61	0.49	1.68	1.65	7.61
	RRII 105	50.96	8.56	29.66	10.46	96.10
	RRII 118	53.73	6.40	22.16	31.86	97.83
Latex yield	*RRII 203*	42.89	5.96	20.64	11.23	72.56
	RRIM 600	59.60	8.00	27.71	19.30	99.26
	PB 235	41.62	6.33	21.92	15.72	83.20
	RRII 105	0.25	0.05	0.18	0.01	0.53
	RRII 118	0.34	0.08	0.27	0.03	0.88
Girth increment	*RRII 203*	0.33	0.07	0.24	0.02	0.68
	RRIM 600	0.35	0.07	0.25	0.03	0.72
	PB 235	0.40	0.09	0.31	0.04	0.85

presented in the table - 3. Altitude had highly significant followed by moderately significant negative associations with rubber yield and latex yield respectively. It was positively associated with the dry rubber content and girth increment while plugging index had no correlation with the altitude. Strong association was observed with rubber yield and dry rubber content. Rubber yield had very strong and highly significant correlation with latex yield followed by plugging index, which was negative. Dry rubber content and girth increment had no association of significance with rubber yield. Dry rubber content and plugging index had sole significant relationship with girth increment and latex yield respectively. Realisation of almost negligible negative correlation of rubber yield with dry rubber content was in agreement with the finding of Vinod *et al.*, 2000. Correlation coefficients obtained in this study for relationship between latex yield and rubber yield, latex yield and plugging index were higher as reported earlier (Chandrasekhar, 1994).

Description of Multiple Regression

The contributions of four yield components and two environmental factors such as months and altitudes (as detailed in Table 1 in Materials and Method) towards the expression of clone specific rubber yield were ascertained and explicated in table 4 and 5. All the yield components as well as environmental factors were included in the initial model as independent variables towards the dependent factor rubber yield with regard to 5 different clones in the multiple backward regression analysis. Stepping down revealed in the final models, those selections of predictors among

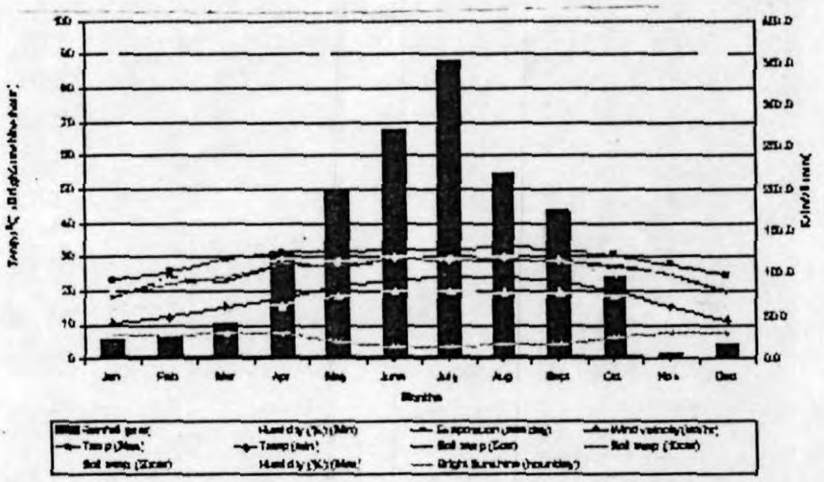

Fig. 2. Mean monthly meteorological parameters over three years at Guwahati

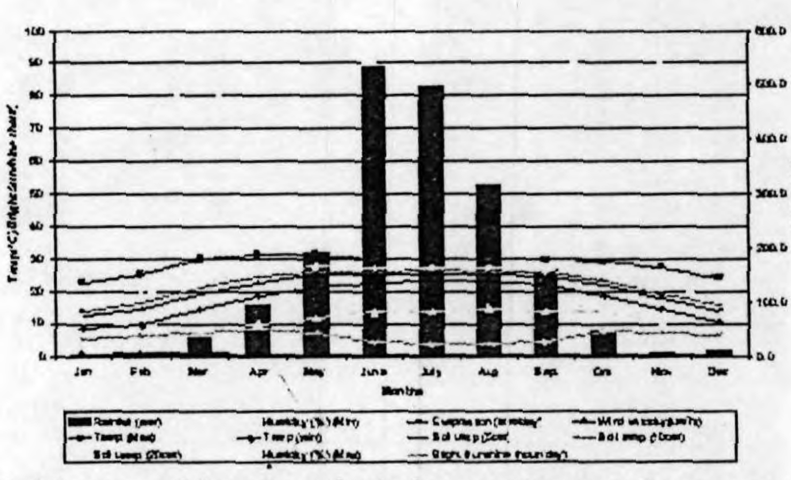

Fig. 3. Mean monthly meteorological parameters over three years at Tura

the independent variables, towards the realization of the criterion factor as rubber yield, were different in each clone indicating the existence of different pathways for rubber yield in different genotypes (table 4). The suitability of initial and final models with regard to each clone for prediction of rubber yield is confirmed by the significance of regression indices. The above contention is confirmed by the lesser value of residual sum of squares than that of regression sum of squares and high significance of the F statistics (table 5). Moreover in each case the regression coefficients being nearly 1 (table 4) are also indicative of the fitness of the model.

Rubber yield of clone: RRII 105

Multiple correlation and regression coefficient of rubber yield of RRII 105 with altitude, different months of the year and yield components started with $R = 0.954$ and $R^2 = 0.911$. The regression model in the present study indicated that the variability observed in the rubber yield of clone RRII 105 was caused by the variability of altitude, different months of the year and yield components to the tune of at least 91%. Positive and high value of R indicated prevalence of a linear and strong inter-relationship between criterion and predictors.

Table 3. Correlation Coefficients Between Rubber Yield and Yield Components at Varied Altitude

	ALT	RY	DRC	PI	LY	GI
ALT	1.000	-.522**	.614**	.000	-.475*	.424*
RY		1.000	-.148	-.583**	.963**	-.002
DRC			1.000	.085	-.209	.848**
PI				1.000	-.651**	-.019
LY					1.000	-.057
GI						1.000

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table 4. Multiple Step Down Regressions of Rubber Yield and Yield Components at Varied Altitude

Clone	Step	R	R^2	Equation
RRII 105	Initial	0.954	0.911	$RY_1 = 5.514 - (0.01033) ALT + (0.414) MONTH - (0.11) DRC_1 + (0.756) PI_1 + (0.238) LY_1 + (6.507) GI_1$
	Final	0.948	0.898	$RY_1 = 7.960 - (0.009796) ALT + (0.247) LY_1$
RRII 118	Initial	0.938	0.880	$RY_2 = - 0.3841 - (0.00911) ALT + (0.240) MONTH + (0.555) DRC_2 - (1.438) PI_2 + (0.176) LY_2 + 2.480 GI_2$
	Final	0.917	0.841	$RY_2 = -11.561 + (0.463) DRC_2 + (0.247) LY_2$
RRII 203	Initial	0.943	0.888	$RY_3 = -3.275 - (0.01138) ALT + (0.255) MONTH + (0.337) DRC_3 - (0.06102) PI_3 + (0.199) LY_3 - (2.329) GI_3$
	Final	0.940	0.884	$RY_3 = -3.032 - (0.01023) ALT + (0.300) DRC_3 + (0.224) LY_3$
RRIM 600	Initial	0.981	0.961	$RY_4 = -3.313 - (.007939) ALT + (0.342) MONTH + (0.168) DRC_4 + (0.06476) PI_4 + (0.255) LY_4 + (4.361) GI_4$
	Final	0.977	0.955	$RY_4 = 1.175 - (0.005936) ALT + (0.269) LY_4 + (9.809)$
PB 235	Initial	0.977	0.954	$RY_5 = -2.534 - (0.001845) ALT + (0.106) MONTH + (0.244) DRC_5 - (0.448) PI_5 + (0.265) LY_5 - (3.131) GI_5$
	Final	0.972	0.945	$RY_5 = 1.003 + (0.290) LY_5$

Rubber yield of clone RRII105 = 5.514-(0.01033) altitude+(0.414) month – (0.11) dry rubber content +(0.756) Plugging Index + (0.238) latex + (6.507) girth increment.

It was revealed that higher the altitude, lower the rubber yields. Rubber yield got a boost during the months at the end of the year. The more dry rubber content did not enhance rubber yield while greater plugging index; latex yield and girth increment were responsible for higher rubber yield in clone RRII 105. While stepping down, at the final step the regression equation included only the regression coefficients of altitude and latex yield, the variability of which seemed to predict 90% towards the rubber yield.

Rubber yield of clone RRII 118

The initial and final R and R^2 being 0.938; 0.917 and 0.880; 0.841, *the regression models* indicated that the variability observed in the rubber yield of clone RRII 118 was caused by the *variability of altitude, different months of the year* and yield components to the tune of at least 88% initially and then 84% of the variability was *accounted for due to that of dry rubber content* and latex yield. Positive and high values of R indicated that the independent variables led a *linear and strong relationship with the criterion* variable.

The initial equation of rubber yield in clone RRII 118 = -0.3481 - 0.00911 altitude+ 0.240 month + 0.555 dry rubber content – 1.438 Plugging Index + 0.176 latex yield + 2.480 girth increment.

The equation explained the relationship that with lower altitude, rubber yield increased during the months at the end of the year in tandem with greater dry rubber content, lesser plugging index; greater latex yield and girth increment.

The final model included only the regression coefficients of DRC and latex yield, the *variables of which seemed to be the highest* contributing factors towards rubber yield.

Rubber yield of RRII 203

Multiple correlation and regression coefficients in both the models of rubber yield of clone RRII 203 with altitude, different months of

Table 5. ANOVA

Clone		Model	Source		SS	df				MSS			F
RRII 105	Initial	Regression	Residual	Total	3294.372	321.897	3616.269	6	17	23	549.062	1.935	28.997*
	Final	Regression	Residual	Total	3246.627	369.642	3616.269	2	21	23	1623.314	17.602	92.223*
RRII 118	Initial	Regression	Residual	Total	1904.156	260.236	2164.392	2	21	23	317.359	15.308	20.732*
	Final	Regression	Residual	Total	1819.964	344.428	2164.392	2	21	23	909.982	16.401	55.482*
RRII 203	Initial	Regression	Residual	Total	1416.329	177.760	1594.155	6	17	23	236.066	10.456	22.576*
	Final	Regression	Residual	Total	1409.628	184.527	1594.155	3	20	23	469.876	9.226	50.928*
RRIM 600	Initial	Regression	Residual	Total	4067.856	163.145	4231.001	6	17	23	677.976	9.597	70.647*
	Final	Regression	Residual	Total	4042.149	188.852	4231.001	3	20	23	1347.3831	9.443	142.692*
PB 235	Initial	Regression	Residual	Total	3523.950	169.595	36.93.545	6	17	23	587.325	9.976	58.873*
	Final	Regression	Residual	Total	3489.050	204.495	3693.545	1	22	23	3489	9.295	375.359*

the year and yield components were R = 0.943; 0.940 and R^2 = 0.888; 0.881. Therefore the variability observed in the rubber yield of clone RRII 203 was predicted by the variability of independent factors to the extent of at least 88%. Positive and high values of R indicated that independent variables converged in a linear and strong relationship with the yield.

Rubber yield of clone RRII 203 = -3.275 - 0.0138 altitude + 0.255 month + 0.337 dry rubber content - 0.06102 Plugging Index + 0.199 latex yield -2.329 girth increment.

The initial model elucidated that lower altitude and girth increment coupled with greater dry rubber content and latex yield, enhanced rubber yield was expected during the months at the end of the year.In the final step the regression equation included only the regression coefficients of altitude, DRC and latex yield as predictors towards rubber yield.

Rubber yield of RRIM 600

Coefficients multiple correlations and determinations of rubber yield of clone RRIM 600 with altitude, different month of the year and yield components were R = 0.977; 0.972 and R^2 =0.954; 0.945 respectively.The regression model at the initial step revealed that the variability observed in the rubber yield of clone RRIM 600 was caused by the variability of altitude, different months of the year and yield components to the tune of at least 95%, which remained almost the same at the final model. The criterion had a linear and strong relationship with the independent variables on account of positive and high value of R.

Rubber yield of clone RRIM 600 = -3.313 - 0.007939 altitude + 0.342 month + 0.168 dry rubber content -0.06476 Plugging Index + 0.255 latex yield of RRIM 600 - 4.361 girth increment.

The direction of relationship explained that higher the altitude, lower was the rubber yield. Rubber yield was accentuated during the months at the end of the year. The more was the dry rubber content higher was the rubber yield while lesser plugging index, girth increment but higher latex yield were responsible for higher rubber yield in clone RRIM 600.

The final model included the regression coefficients of altitude, girth increment and latex yield, the variables of which seemed to affect the most towards rubber yield.

Rubber yield of clone PB 235

Multiple correlations of rubber yield of clone PB 235 with the yield components at varied altitude during different months of the year explained a positive linear and very strong association as R = 0.977 initially and then 0.972. Regression coefficients of initial and final models being R^2 = 0.954 and 0.945 were indicative that the yield components at varied altitudes and months of the year account for a total of 95% towards the expression of rubber yield. At the final step only latex yield appeared to be responsible for bringing about the maximum variability in the rubber yield. The initial equation estimated that rubber yield of PB 235 = -.2.534 – (0.00185) altitude + (0.106) month + (0.244) DRC – (0.448) PI_5 + (0.265) LY_5 – (3.131) GI_5. With the selection of plantation sites at lower altitude, increased dry rubber content and latex index, lowering of plugging index and girth increment the rubber yield of PB 235 was expected to reach high. Finally, latex yield appeared to be the predictor for the criterion.

In case of all the clones the initial models appeared to give better prediction of a yield-yield component and environment model as was observed by the higher value of realized multiple regression coefficients. Nevertheless, the final model determined that altitude was a deciding factor towards rubber yield in case of only clones RRII 105, RRII 118 and RRIM 600 while for other clones the effect of altitude was almost negligible. Yield components under the influence of difference environmental factors were always at variance in magnitude and even sometimes, in terms of direction of relationship towards yield outputs among the clones. Altitude had negative but month and latex yield had positive regression indices respectively for realisation of rubber yield irrespective of clonal variations. Except for RRII 105, other clones had positive index in case of dry rubber content. Positive regression indices for plugging index and girth increment were observed in RRII 105 and RRIM 600 while in other three clones negative direction for these expressions was prevalent.

CONCLUSION

It may be concluded that genotypic variation of the clones interacted with the variability of altitudes and months of the year. Altitude had significant correlation with dry rubber content, rubber yield, latex yield while rubber yield showed significant correlation with latex yield and plugging index respectively. The relationship between dry rubber content and girth increment was highly significant. Plugging index was significantly correlated with latex yield. Fitness of multiple regression models with regard to each clone for prediction of rubber yield was confirmed by the significance of regression indices as evident by the lesser value of residual sum of squares than that of regression sum of squares and high significance of the F statistics. Besides the regression coefficients being nearly 1 in each case confirmed the suitability of the model. In case of all the clones the initial models appeared to give better prediction of a yield-yield component and environment model as was observed by the higher value of realized multiple regression coefficients. Nevertheless, the final model determined that altitude was a deciding factor towards rubber yield in case of only clones RRII 105, RRII 118 and RRIM 600 while for the clones RRII 203 and PB 235, the effect of altitude was almost negligible.

ACKNOWLEDGEMENTS

The authors wish to record their deep sense of gratitude to Dr N M Mathew for providing necessary facilities. Thanks to the colleagues of RRS Guwahati and Tura for their support while recording of observations. Thanks are also due to Ms M Chaudhuri, Senior Research Officer, Central silk Board, Guwahati for rendering help in statistical analyses.

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