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SEASONAL CHANGES IN PHYSIOLOGICAL CHARACTERISTICS AND YIELD IN NEWLY OPENED TREES OF *HEVEA BRASILIENSIS* IN NORTH KONKAN

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Seasonal changes in physiological characteristics and yield were studied in *Hevea brasiliensis* in the North Konkan region. This is a non-traditional rubber growing area where the crop experiences severe drought in summer months. The study was carried out in newly opened trees of clones GT 1 and RRIM 600. The per tap dry rubber yield in summer months was extremely low and not economical. The estimated first year yield ha^{-1} for the remaining period was 493 kg for GT 1 and 549 kg for RRIM 600. The extreme soil and atmospheric moisture deficits resulted in very low plant moisture status and high plugging indices. Stomatal conductance and transpiration rates were also severely inhibited throughout the day. Partial defoliation and leaf margin drying were observed during this period. In general, RRIM 600 maintained relatively higher yield and plant moisture status.

Key words:- Hevea brasiliensis, Drought tolerance, Yield components, Water relations, Konkan region.

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INTRODUCTION

The traditional rubber growing tract in India extends from Kanyakumari (8°N) to Mangalore (12°N). The total production from the region is not sufficient to meet the country's full requirement. Further expansion of area under rubber in this zone to increase the production is not feasible due to environmental and socio-economic reasons. Therefore it became necessary to explore the possibilities of extending rubber cultivation to other less congenial but potential areas (Sethuraj *et al.*, 1989). One such region identified is the Konkan region of Western India (15° to 20°N).

In this region prolonged severe soil moisture deficits and high summer temperatures are the major environmental constraints for growth and productivity of rubber. Effects of these adverse conditions on growth of *Hevea* is now fairly understood (Sethuraj *et al.*, 1989; Bhaskar *et al.*, 1990). However, at present there is no data on the yield performance of *Hevea* in the region. Effects of extreme stress conditions on yield and yield components and plant moisture status are not known, though such information on the effects of drought in the traditional region is available (Gururaja Rao *et al.*, 1988; Devakumar *et al.*, 1988; Vijayakumar *et al.*, 1988). The objective of the present study was to understand the water relations and yield performance in *Hevea brasiliensis* under the prevailing conditions of North Konkan region, Maharashtra State. The paper, for the first time, reports the observations made on two clones of *Hevea* during the first year of tapping in the region.

MATERIALS AND METHODS

The study was carried out in a plantation at Parali (18° 03' N, 73°13' E, 41 m) in Raigad District of Maharashtra State. The climate of the location is typical of the North Konkan region with annual rainfall of more than 2500 mm. The entire rainfall is received from the middle of June to the middle of October. Mild winter is experienced from December to February. High summer temperatures are experienced during April-June period. Weather parameters typical for the study area were collected from the Regional Research Station of Rubber Research Institute of India located in the adjacent district.

Observations were made on two popular clones, GT 1 and RRIM 600 planted in 1980. Ten trees of each clone with comparable girth were selected for the study. All trees were under ½S d/2 system of tapping. During the rainy season, trees were rainguarded. Monthly recordings of latex yield (ml $tree^{-1}$ tap^{-1}), dry rubber yield (g $tree^{-1}$ tap^{-1}), initial flow rate (F, ml cm^{-1} min^{-1}), per cent rubber content (Cr, w/v), plugging index (p), latex vessel pressure potential (P_{lv}, MPa) before and after tapping, latex solute potential ($\psi\pi$,–MPa), leaf water potential (ψ_l,–MPa), stomatal conductance (g_s, m moles m^{-2} s^{-1}) and transpiration (E, m moles m^{-2} s^{-1}) were made from March 1989 to February 1990, except for November 1989 and January 1990.

Plugging index was determined following the method of Milford *et al.* (1969). Initial flow rate and hence the plugging index could not be determined during the extreme dry season due to very low latex yield. Latex vessel pressure potential was estimated using disposable manometers comprising No. 49 polythene surgical tubing sealed at one end and fitted with 21 gauge hypodermic syringe needle at the other (Raghvendra *et al.*, 1984).

Latex solute potential and leaf water potential were recorded using C-52 sample chamber psychrometer connected to HR 33 T dew point microvoltmeter (Wescor Inc., Logan, USA) following the procedure reported earlier (Devakumar *et al.*, 1988). Stomatal conductance and transpiration rates were measured using LI–1600 steady state porometer (Li–Cor Instruments, USA). Leaf water potential was determined at pre-dawn and afternoon and stomatal conductance and traspiration were measured at 9.30 – 10.30 h and 12.30 – 13.30 h on each day of observation. The diurnal changes in ψ_l, g_s and E were also monitored in three typical days representing wet, moderate stress and severe stress seasons. The diurnal measurements started from 6.00 h at two hourly intervals and ended at 18.00 h. Mature and healthy leaves were sampled for the measurements.

All the selected trees were sampled for latex and dry rubber determinations. Four trees were sampled for the measurements of F and P_{lv}. All other parameters were measured on three random plants for each clone.

The soil moisture content at three depths (0–30, 30–60 and 60–90 cm) in the plantation was determined by gravimetric method. The sampling was done at random in the field (irrespective of clone) and three replications were taken for each depth. Field capacity (FC) and permanent wilting point (PWP) were determined using pressure plate apparatus (Soil Moisture Equipment Corporation, USA).

Dry (February–May) and wet (June–December) season data were analysed separately for clonal comparison. Seasonal differences within a clone were also tested.

RESULTS

Data on monthly rainfall, mean monthly temperatures and vapour pressure deficits (VPD) during the study period are presented in Table 1. The rainfall was confined almost exclusively to the period of June–October. The dry period extended from the middle of October to the middle of June. During April-June period, the mean maximum temperatures were higher than 37°C. The VPD was also high during the dry season.

Table 1. **Rainfall, air temperatures and vapour pressure deficits at Dapchari**

Month (1989-90)	Rainfall (mm)	T Min (°C)	T Max (°C)	VPD (KPa)
March	0.0	17.4	34.6	1.61
April	0.0	21.0	37.6	1.97
May	0.0	23.8	37.9	1.43
June	287.8	23.4	38.5	0.61
July	821.2	24.0	30.7	0.37
August	604.0	23.5	28.4	0.25
September	228.8	23.0	30.7	0.41
October	79.4	20.2	34.0	1.17
November	0.0	18.4	34.4	1.53
December	0.0	14.2	30.9	1.17
January	0.0	14.5	34.0	1 52
February	0.0	14.2	32.8	1.46

The soil moisture status in different months in the plantation is presented in Table 2. Severe soil moisture stress was experienced from February until the onset of monsoon in June. The soil moisture content upto 90 cm depth was at or below PWP from March onwards. There was combined stress of soil moisture deficit and high atmospheric temperatures.

Table 2. **Volumetric soil moisture content (cm) in the plantation**

Months (1989-90)	Soil depths (cm) 0-30	30-60	60-90	0-90
March	6.98	7.85	8.17	22.99
April	6.62	6.22	7.05	19.89
May	6.63	6.20	7.16	19.99
June	10.74	10.09	9.54	30.37
July	S	S	S	S
August	S	S	S	S
September	S	S	S	S
October	10.97	13.03	13.51	37.51
November	—	—	—	—
December	8.44	9.23	9.43	27.10
January	—	—	—	—
February	7.62	8.22	9.37	25.22
PWP	7.73	7.17	6.99	21.90
FC	12.19	11.23	11.23	34.64

S: Saturated
— Not determined
PWP: Permanent wilting point
FC: Field capacity

The plants started wintering by the end of December. From April onwards severe leaf injury was visible as chlorosis and leaf margin drying. Considerable defoliation was also noticed during this period. The afternoon leaf temperatures touched 40–43°C.

The dry rubber yield (g $tree^{-1}$ tap^{-1}) obtained in different months from the clones are presented in Table 3. Seasonal means are presented in Table 4. Very low yield was recorded from March to May. With the onset of monsoon, the yield started increasing and the highest yield was recorded in the month of December. In most of the months RRIM 600 showed higher yield than GT 1. The difference in dry rubber yield of the clones was not significant in the wet season, but was significantly higher for RRIM 600 in the dry season.

Table 3. **Monthly dry rubber yield (g tree^{-1} tap^{-1}) in the first year of tapping**

Months (1989-90)	Clones	
	GT 1	RRIM 600
March	2.79	3.28
April	4.58	5.54
May	4.05	6.10
June	6.65	7.45
July	8.68	12.46
August	13.33	20.44
September	13.67	11.72
October	17.57	17.51
November	---	---
December	24.53	24.03
January	---	---
February	10.03	12.91
Mean	10.59	12.14
SE	±2.05	± 2.05

--- not recorded

The monthly changes in latex yield, F and p are presented in Figure 1. Seasonal means of the parameters including Cr are presented in Table 4. The latex yield, F and p were higher in RRIM 600 in most of the months. The p in the dry season was too high to be determined because of the practical difficulty in measuring the very low F. Rubber content was found to be higher in GT 1 in the wet season whereas in the dry season it was higher in RRIM 600.

Monthly changes in pre-tapping and post-tapping P_{lv}, $\psi\pi$, pre-dawn and afternoon ψ_l and g_s are given in Figures 2 – 4. Seasonal means are presented in Table 4. Diurnal variations in ψ_l for three typical days in three distinct periods are presented in Figure 5. Diurnal variations in g_s and E measured in two typical days in moderate and severe stress periods are presented in Figure 6.

Both pre-tapping and post-tapping P_{lv} were higher in RRIM 600 in most of the months. Lowest values were observed in May and the highest values in June. The pre-tapping P_{lv} declined substantially during March-May with the lowest value in May and increased to the highest with the onset of monsoon and again declined slowly afterwards. Pre-tapping P_{lv} was significantly higher for RRIM 600 in both the seasons. Post-tapping P_{lv} also showed similar trend with that of pre-tapping P_{lv}. There was no clonal difference in the wet season. But in the dry season it was higher for RRIM 600. In GT 1 it was even negligible. Seasonal difference in post-tapping P_{lv} was, however, not significant in RRIM 600.

The $\psi\pi$ was less than –1.00 MPa in March–May. With the onset of monsoon the $\psi\pi$ rose to –0.5 MPa and remained constant till October. Clone RRIM 600 maintained significantly higher $\psi\pi$ in March–May period.

The pre-dawn ψ_l values were also higher for RRIM 600 in most of the months. Afternoon ψ_l was significantly higher for the clone only in the dry season. In the extreme dry period of March–May, the pre-dawn ψ_l values touched –1.5 to –1.8 MPa. Quick rise in the values were noticed with the onset of monsoon and the higher values were maintained till September–October only.

The afternoon ψ_l was below –2.0 MPa during the dry period. With the onset of monsoon, it increased to around –1.0 MPa. Afterwards there was gradual decline upto December. In February, 1990 the afternoon ψ_l increased to around –1.5 MPa.

Table 4. **Yield, yield components and components of plant moisture status in dry and wet seasons**

Parameter	Dry season			Wet season		
	GT 1	RRIM 600	C.D. 0.05	GT 1	RRIM 600	C.D. 0.05
Latex yield (ml $tree^{-1}$ tap^{-1})	18.41	22.87*	3.38	53.61	62.04*	7.59
Dry rubber yield (g $tree^{-1}$ tap^{-1})	5.36	6.96**	0.957	14.07	15.60	NS
Rubber content (Cr, %, w/v)	33.71	36.14*	1.73	27.93	26.81*	0.956
Initial flow rate (F, ml cm^{-1} min^{-1})	—	—	—	0.049	0.065**	0.0075
Plugging index (p)	—	—	—	3.16	4.07*	0.682
Pre-tapping latex turgor (P_{lv}, MPa)	0.605	0.715*	0.101	0.809	0.863*	0.042
Post-tapping latex turgor (P_{lv}, MPa)	0.051	0.183*	0.415	0.169	0.169	NS
Latex solute potential (Ψ_l, –MPa)	1.076	0.955*	0.116	0.528	0.528	NS
Pre-dawn leafwater potential (Ψ_l, –MPa)	1.55	1.37*	0.084	0.77	0.57*	0.063
Afternoon Ψ_l (–MPa)	2.045	1.814*	0.173	1.43	1.32	NS
Stomatal conductance (m mole m^{-2} s^{-1})						
9.30–10.30 hrs	38.51	77.24*	9.95	—	—	—
12.30–13.30 hrs	17.96	56.35**	7.13	—	—	—

— Not recorded * Significant at P = 0.05 ** Significant at P = 0.01 NS: Not significant

Note: Differences between seasons within a clone for all the parameters were highly significant (P = 0.01) except for post-tapping P_{lv} in clone RRIM 600

In both the clones, the diurnal changes in ψ_l were similar in the morning hours only during wet and moderate stress periods. However, under severe stress ψ_l values were always significantly lower. Mid-day and afternoon ψ_l values were lower during the stress periods. The mid-day and afternoon ψ_l during mild and severe stress periods were almost similar. Rise in ψ_l was noticed after 14.00 hours both during mild stress and wet periods. However, this trend was not noticed in the severe stress period even upto 18.00 hours. The pattern of diurnal changes in ψ_l in all the seasons were comparable for both the clones.

Lower g_s was observed from March to May and from December to February. In general, RRIM 600 maintained higher g_s compared to GT 1. The diurnal pattern of g_s and E indicate maximum stomatal opening at 8.00 h. In RRIM 600, the g_s during forenoon hours was higher than that of GT 1. Severe inhibition of g_s and E was observed throughout May. Clone RRIM 600 showed higher E rates during both the days of diurnal observations.

DISCUSSION

In the North Konkan region, continuous absence of rainfall for nearly eight months, coupled with higher vapour pressure deficits in summer months creates adverse conditions for latex production. The annual water deficit in the region is around 1070 mm

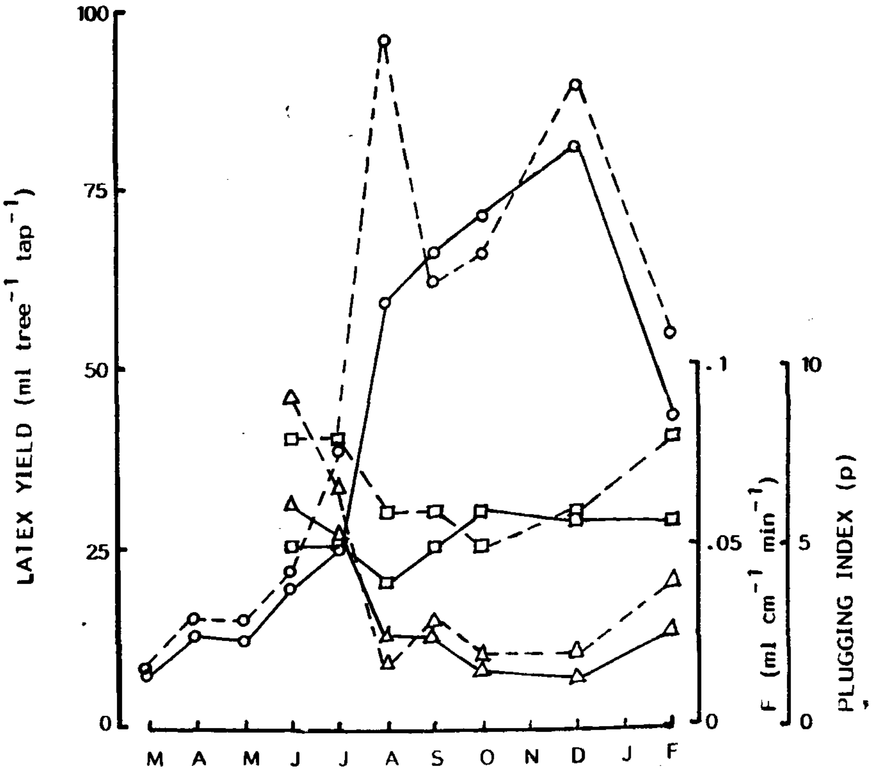

Fig. 1. Seasonal variations in latex yield (O), initial flow rate (□) and plugging index (△) in GT 1 (—) and RRIM 600 (- - -)

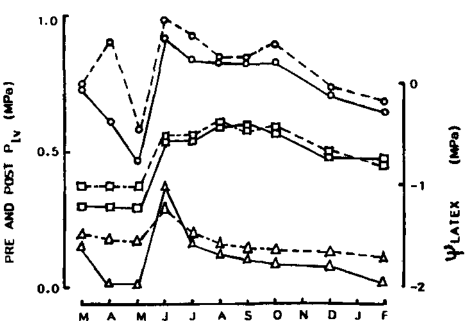

Fig. 2. Seasonal variations in pre-tapping P_{lv}(O), post-tapping P_{lv} (△)and $\Psi\pi$ (□) in GT 1 (—) and RRIM 600 (- - -)

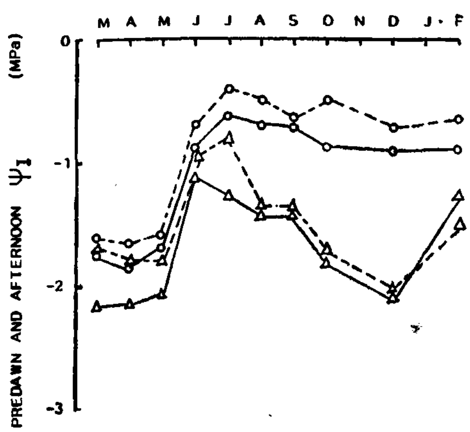

Fig. 3. Seasonal changes in pre-dawn (O) and afternoon (△) leaf water potential in GT 1 (—) and RRIM 600 (- - -)

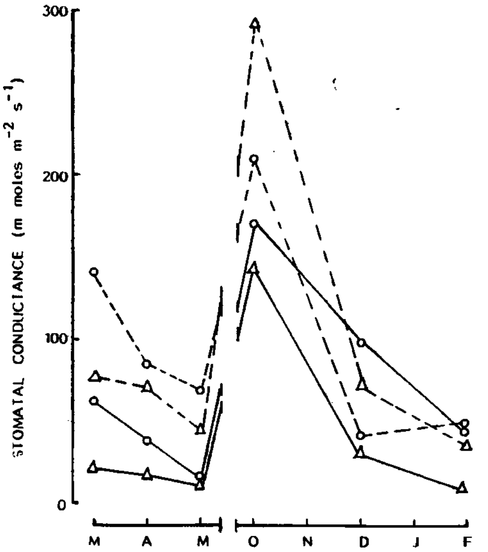

Fig. 4. Seasonal variations in stomatal conductance during 9.30—10.30 hrs (O) and 12.30—13.30 hrs (△) in GT 1 (—) and RRIM 600 (- - -)

whereas it is around 350 mm in the traditional region (Rubber Research Institute of India, 1988). The normal soil moisture depletion in the region is more than what was reported for the traditional region during an unusual drought experienced in 1987 (Vijayakumar *et al.*, 1988).

First year yield ha^{-1} (from 300 trees in a stand of 400 trees ha^{-1}) estimated from the monthly yield recordings, indicates an yield of 550 kg for GT 1 and 622 kg for RRIM 600. For the traditional region, Toms Joseph and Haridasan (1990) have reported yield of 672 kg ha^{-1} for GT 1 and 681 kg ha^{-1} for RRIM 600 in the first year of tapping. When compared to these, the reduction in yield of the clones in the North Konkan is only marginal.

The difference between the estimated first year yield of the two clones in the region was found to be statistically not significant. The very low yield recorded during the summer months of March–May is un-economical suggesting discontinuation of tapping during this period to be ideal. Tapping can be started after the onset of monsoon in mid-June. After deducting the yield obtained in summer months, the first year yield works out to be 493 kg ha^{-1} for GT 1 and 549 kg ha^{-1} for RRIM 600. Tapping rest in summer may, however, result in slight increase in yield during the rest of the year. The monthly distribution of rainfall and the yield pattern indicate requirement of tapping with rainguarding.

Latex yield in *Hevea* shows a post-wintering depression and subsequently it increases gradually. Maximum yield is obtained before the next refoliation. Soil moisture stress increases the severity of the yield depression due to wintering. In the traditional rubber growing region of India combined effect of wintering and soil moisture stress on latex output is experienced annually. Differential quantification of the effects of the two factors on latex production has not been made so far.

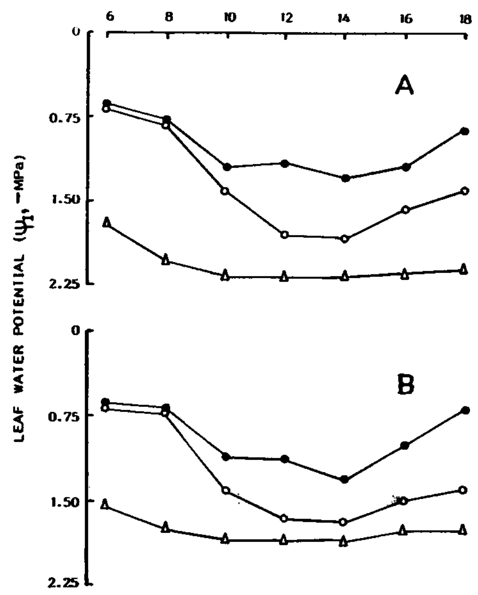

Fig. 5. Diurnal variations in leaf water potential in wet (●, September), moderate dry (O, October) and extreme dry (△, May) months in GT 1 (A) and RRIM 600 (B)

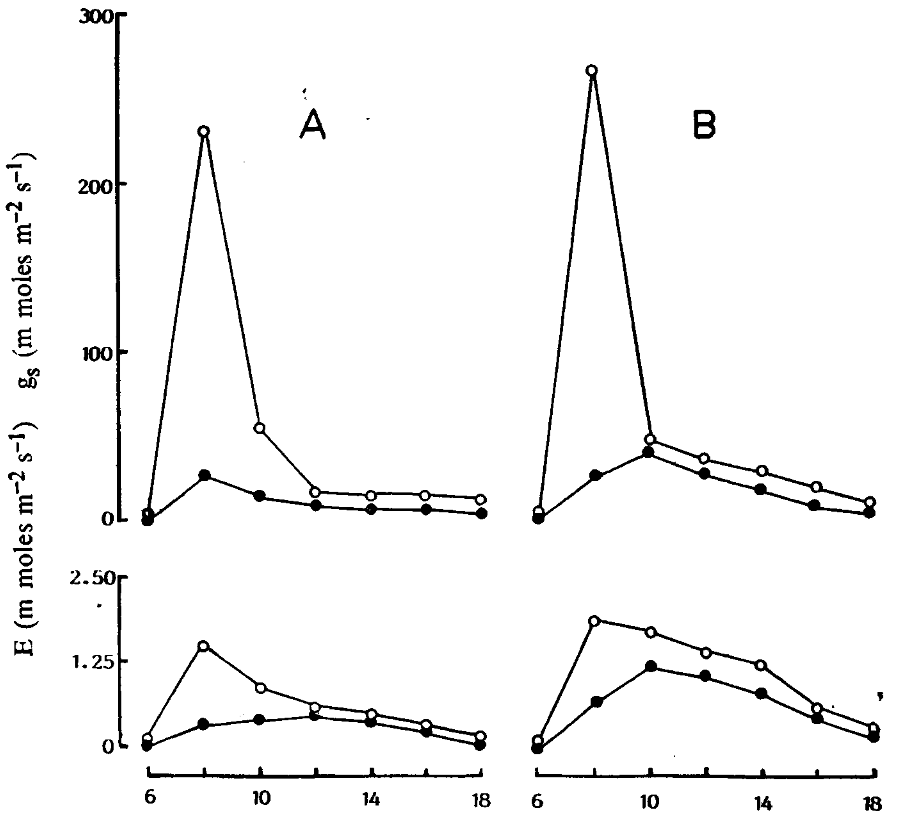

Fig. 6. Diurnal changes in stomatal conductance (g_s) and transpiration (E) during moderate dry (O, October) and severe dry (●, May) seasons in GT 1 (A) and RRIM 600 (B)

The drastic reduction in yield in summer months reported here was apparently due to the extremely low levels of soil moisture and high VPD. The total yield obtained in these months was only 11 per cent of that obtained during the rest of the year. Vijayakumar *et al.* (1988) reported that the mean monthly yield obtained in the summer months in a drought year in the traditional region was as much as 64 per cent of the mean wet month yield for GT 1 and 54 per cent for RRIM 600. However, the corresponding figures obtained from the study reported here are 28 per cent for GT 1 and 32 per cent for RRIM 600. Thus, unlike in the traditional region, RRIM 600 is found to be more drought tolerant than GT 1 under the extreme dry conditions of the Konkan region. However, when compared to clones like Tjir 1 and RRII 118, both GT 1 and RRIM 600 are drought tolerant (Vijayakumar *et al.*, 1988). This can be one of the reasons for the absence of marked difference in the summer yield of these two clones in the Konkan region. However, the higher mean monthly yield of RRIM 600 was due to higher latex output and dry rubber content.

Very low yield in summer months was associated with very high plugging index as reported earlier (Devakumar *et al.*, 1988). The high plugging index in summer months was associated with significant decrease in pre-tapping P_{lv} and high Cr. The fall in pre-tapping P_{lv} in spite of osmotic adjustment, was due to the high soil moisture tensions. The mean estimated pre-tapping water potential of the bark (ψ *bark*) in summer was –0.471 MPa for GT 1 and –0.240 MPa for RRIM 600. These values indicate that roots were drawing water from lower depths than studied, with RRIM 600 having deeper roots compared to GT 1. Monteny *et al.* (1985) have also reported similar indirect evidence for water absorption by *Hevea brasiliensis* from deeper layers of soil.

In GT 1, soon after the receipt of rainfall, recovery in post tapping P_{lv} was noticed. However, this was not accompanied by a concomitant decrease in p, though considerable increase in F was observed. These findings are in agreement with the earlier report for the traditional region (Rubber Research Institute of India, 1988). The present data also indicate that drought acts mainly indirectly through increased rate of plugging resulting in low yield. Although the pre-tapping P_{lv} was highest in June in both the clones (Fig. 2), the highest yield was recorded in December when the pre-tapping P_{lv} was lower by more than 0.2 MPa. The variation in P_{lv} had only a minor effect on seasonal change in the latex output, though diurnal P_{lv} changes strongly influence latex flow (Paardekooper and Sookmark, 1969). Thus as discussed earlier (Devakumar *et al.*, 1988; Vijayakumar *et al.*, 1988) drought induced biochemical changes in latex properties are important in addition to those due to wintering.

Earlier studies (Devakumar *et al.*, 1988) have shown that maintenance of higher plant water potential in summer months is one of the factors associated with drought tolerance. They found higher stomatal resistance and sap flow rate in the tolerant clone RRII 105 when compared to RRII 118 in which yield depression was more. However, the present study shows that in RRIM 600 higher ψ_l and P_{lv} are maintained in spite of the higher g_s and E (Figs. 3–6). Induction of deeper and probably denser roots might be responsible for the higher plant moisture status.

The pattern of monthly changes in yield, and p are comparable to that of the traditional region. The immediate recovery in pre-tapping P_{lv} is similar to the observations reported earlier (Rubber Research Institute of India, 1988). Also, there was sudden increase in ψ_π in the same month. The pre-tapping P_{lv} during the rainy months could not be completely accounted for by the ψ_π alone. Building up of root pressure might be one of the reasons for this. The very high ψ_π observed in rainy months need to be studied further. The incomplete recovery of pre-dawn ψ_l in June unlike in traditional region (Rubber Research Institute of India, 1988) might be due to more damage caused to the root system in the preceding dry period and higher VPD in the month. Higher afternoon ψ_l in June might be due to the reduction in leaf area that was caused by the preceding extreme drought. The higher afternoon ψ_l noticed in February can be attributed to post wintering effect, physiological immaturity and lower g_s of the leaves (Fig. 4). The lower pre-dawn ψ_l observed in the wet months might be due to the possible errors associated with the measurements using thermocouple psychrometer.

The present study on the diurnal changes in ψ_l shows that in the morning hours it is comparable during wet and moderate stress periods. However, in the peak stress period there was a severe reduction in ψ_l and g_s unlike in the traditional region where the g_s was similar in wet and dry seasons in the morning hours (Devakumar *et al.*, 1988). Wet season observations of g_s using steady state porometer were unrealistically high (exceeding 1000 m moles m^{-2} s^{-1}). The reason for obtaining such high values could be an error in porometry due to very high relative humidity (Garnier and Berger, 1987).

The observations presented in the paper indicate that reasonable yield can be obtained in the North Konkan region in spite of the extreme drought in summer. Tapping in these months may not be economical. The studies on water relations show that maintenance of better plant moisture status (ψ *plant*) under drought conditions would lead to better yield performance. A deeper and denser root system, lower root resistance to water movement and lower stomatal conductance, would help in maintaining higher ψ*plant*. Clonal variations in the sensitivity of the biochemical mechanisms regulating plugging to plant moisture status is also important in determining yield performance in summer months. The data are being processed further for establishing quantitative relationships among the various parameters.

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