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STOMATAL RESPONSES OF *HEVEA* TO ATMOSPHERIC AND SOIL MOISTURE STRESS UNDER DRY SUBHUMID CLIMATIC CONDITIONS

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ABSTRACT

The effect of prolonged cyclic moisture deficits and high summer temperatures was studied in rubber clones grown in the Konkan region. For this the data on soil moisture, leaf water potential (ψ_l) and stomatal conductance (g_s) were collected in the morning (MN) and afternoon (AN) hours during partial stress (February) and severe stress (May). After analyzing the data, an index of stomatal performance (I_{sp}) was computed for each clone. Predawn(PD)ψ_l ranged from -1.33 to -0.68 MPa and that of AN from -2.14 to -1.75 MPa. The effects of stress conditions were clearly evident from the very low rates of g_s. Afternoon g_s ranged from 6 to 124 mmoles $m^{-2}s^{-1}$. Clone RRIM 600 with highest I_{sp} and girth was the leading clone in girth growth. Clones Tjir 1, GT 1 and PB 235 were last in position. RRIM 612 with rank 3 in I_{sp} was second in girth growth and RRIM 501 with rank 6 in I_{sp} was third in girth growth. The correlation between I_{sp} and girth was 0.79 ($P<0.05$) indicating that I_{sp} may be extended for juvenile identification of drought tolerant clones.

INTRODUCTION

Konkan region in the Western India (15° to 20° N) is one among the non-traditional regions where *Hevea* cultivation is being tried for future expansion. In this region prolonged cyclic moisture deficits and high summer temperatures are the major constraints for the growth and productivity of *Hevea* (Chandrashekar *et al.* 1990; Mohankrishna *et al.* 1991). Therefore, it is of value to know the plant moisture status and stomatal performance as they are immediately affected by the ambient environment. Studies have already been conducted on the subject in the traditional region where the stress conditions are brief and moderate (Devakumar *et al.* 1988; Gururaja Rao *et al.* 1988). Some information is also available on the plants subjected to cyclic stress conditions which are severe and of longer duration (Chandrashekar *et al.* 1990; Mohankrishna *et al.* 1991). However, detailed information over a range of clones is lacking.

The objectives of this paper are to present the variation in stomatal characteristics and plant moisture status of a few *Hevea* clones in time and space as observed *in situ* under the drought conditions of dry sub-humid weather.

MATERIALS AND METHODS

This investigation was carried out in a plantation established in 1982 at the Regional Research Station of Rubber Research Institute of India, Dapchari (Lat:20.04°N; Long:72.04° E; Alt:48m MSL) in Thane district of Maharashtra. The soil is of clay loam type with pH 6.3 to 6.5. Climatic and other characteristics of the location are described elsewhere (Chandrashekar *et al.* 1990; *Mohankrishna et al.* 1991). The clones included in the study were PB 235, RRII 300, GT1, RRIM 501, GI 1, RRIM 612, Tjir 1, PR 107 and RRIM 600. Planting details and cultural practices followed are provided in Chandrashekar *et al.* (1994).

Table 1. Weather conditions of the experimental area in dry months from November 1989 to May 1990 during the study period.

Weather factor	Statistic	M O N T H S					
		Nov	Dec	Jan	Feb	Mar	Apr	May
T min (°C)	Mean	18.4	13.7	14.5	15.9	18.0	21.2	25.3
	Lowest	16.0	9.0	12.0	11.0	13.0	18.0	23.0
	Highest	22.5	16.0	17.0	20.5	22.0	24.0	28.0
T max (°C)	Mean	34.4	32.1	34.0	32.2	33.5	36.1	35.6
	Lowest	32.5	30.0	29.0	27.0	27.5	33.0	31.5
	Highest	36.5	34.0	36.5	38.0	38.5	40.5	39.0
R.H. (%) (7.40 a.m.)	Mean	79.0	78.6	79.5	75.4	77.1	75.3	75.5
	Lowest	46.0	34.0	52.0	48.0	45.0	61.0	61.0
	Highest	95.0	90.0	98.0	95.0	96.0	97.0	97.0
R.H. (%) (2.40pm)	Mean	40.0	42.0	34.0	32.0	35.0	36.0	50.0
	Lowest	21.0	24.0	15.0	13.0	13.0	21.0	27.0
	Highest	60.0	63.0	61.0	60.0	54.0	57.0	65.0
Evapo-ration (mm)	Mean	5.0	4.1	4.8	5.9	6.3	8.0	6.9
	Lowest	2.0	2.0	2.6	3.3	4.0	6.0	2.0
	Highest	6.5	5.6	6.9	7.0	10.0	10.0	9.0
Sunshine duration (Hrs)	Mean	9.5	9.3	10.2	9.4	10.1	11.2	9.1
	Lowest	5.1	5.2	9.3	3.5	8.4	10.1	0.0
	Highest	10.2	10.4	10.4	11.1	10.5	11.4	11.5
Soil moisture (%)	0-30 cm	29.3	23.0	20.7	20.5	19.6	17.9	16.8
	30-60 cm	31.8	30.1	28.5	26.0	25.0	21.5	20.7
	60-90 cm	33.8	32.4	29.0	28.3	26.0	23.0	22.1
Rainfall (mm)		0.0	0.0	0.0	0.0	0.0	0.0	0.0

T min=Minimum temperature; T max=Maximum temperature; R.H.=Relative humidity;
Field capacity = 30.5%; Permanent wilting point =17.5%; Average annual rainfall =>2500 mm

Observations on leaf water potential (Ψ) and stomatal conductance (gs) were made on the nine clones during February 1990 (22/23) and May 1990 (14/15). The months represented end of winter (partial stress) and peak summer (severe stress) respectively. During the days of observations in each month the vapor pressure deficit (VPD) and other weather conditions were similar. In each month, the recordings were made at two times a day i.e., between 9.00 and 9.30 hrs. in the morning (MN) and 12.30 and 13.00 hrs. in the afternoon (AN). The measurement times coincided with the peak hours of photosynthesis (Mohankrishna *et al.* 1991)

Leaf water potentials - measured using C-52 sample chamber psychrometer connected to HR 33T dew point microvoltmeter (Wescor Inc., Logan, USA) were determined at predawn (PD) and afternoon (AN) on each day of porometer observations. Stomatal conductance(g_s) were recorded using LI-1600 Steady State porometer (LI-Cor Instruments, USA). The experimental plots consisted of twenty five plants each in square planting with a spacing of 4.9x4.9 meters. In each clone three plants were sampled for leaf water potential and four for porometer measurements. Mature healthy sun leaves were sampled for all the measurements.

Table 2. *Leaf water potentials (-Mpa) of the clones during predawn (PD) and afternoon (AN) hours in different months*

Clones	February		May	
	PD	AN	PD	AN
RIIM 600	-0.86 a	-1.75 a	-0.68 a	-1.87 a
PR 107	-0.86 a	-2.07 c	-1.00 b	-1.87 a
Tjir 1	-1.13 b	-2.14 c	-1.02 b	-1.89 a
RRIM 612	-1.24 b	-2.04 b	-0.96 b	-1.80 a
GI 1	-1.13 b	-2.04 b	-0.98 b	-2.00 a
RRIM 501	-1.00 b	-2.00 b	-1.27 c	-2.07 b
GT 1	-1.08 b	-1.82 a	-1.31 c	-2.02 b
RRII300	-1.08 b	-2.04 b	-1.31 c	-2.07 b
PB 235	-0.95 a	-1.91 b	-1.33 c	-2.13 b

Means followed by different letters are significantly different at P<0.05 according to single degree freedom comparisons

Weather parameters for the experimental period were collected from the meteorological observatory situated 150 meters away from the experimental site. The soil moisture content at three depths i.e., 0-30, 30-60 and 60-90 cm in the plantation was determined by gravimetric method. The sampling was done at random 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.

The data were analyzed following single degree freedom comparisons (Steel and Torrie, 1980) for finding out similarly comparing clones. A maximum of nine comparisons (equal to the number of treatments) were discerned and therefore, nine scale letter grade system (from a to i) was used to assess the stomatal performance of clones. Letter grades obtained by the clones were converted to grade points (with a=9 and the following letters correspondingly getting a number in the descending series) and an index of stomatal performance (I_{sp}) was computed for each clone as follows.

Table 3. *Stomatal conductance (m moles m^{-2} s^{-1}) measurements of the clones during morning (MN) and afternoon (AN) hours in different months*

Clones	February		May	
	MN	AN	MN	AN
RRIM 600	61.1 c	38.0 b	123.0 a	123.3 a
PR 107	66.7 b	44.5 a	94.1 b	32.1 e
Tjir 1	21.9 f	14.2 e	25.5 f	13.9 f
RRIM 612	65.2 b	25.6 d	75.4 c	55.1 c
GI 1	33.8 e	35.9 b	66.8 d	45.3 d
RRIM 501	83.7 a	27.1 c	16.4 g	11.1 g
GT 1	30.7 e	14.6 e	12.5 h	9.5 g
RRII 300	45.0 d	28.3 c	54.4 e	64.3 b
PB 235	41.5 d	16.9 e	6.3 i	16.4 f

Means followed by different letters are significantly different at P<0.05 according to single degree freedom comparisons.

$$I_{sp} = \sum_{i=1}^{n} x_i t_i$$

Where,

x= grade point obtained by the clone for recordings of different months and

t=frequency of the corresponding grade point.

Similarly comparing clones, whose measurements were not significantly different were given the same grade and hence the grade point.

RESULTS AND DISCUSSION

Weather conditions of the experimental area observed during the study period are presented in Table 1. Average monthly minimum temperatures ranged from 18.4° C to 25.3° C. Lowest temperature was recorded in the month of December and the highest in the month of May. Mean monthly maximum temperatures ranged from 32.2°C to 36.1°C with lowest maximum of 27° C in February and highest maximum of 39° C in May. Range of mean evaporation was from 4 to 8 mm and that of sun-shine hours was 9 to 11.2 hours. Soil moisture was at field capacity in the month of November and

Table 4. ***Computation of the index of stomatal performance (I_{sp})***

Grade Grade point (x)	a 9	b 8	c 7	d 6	e 5	f 4	g 3	h 2	i 1	$I_{sp} = \sum_{x=1}^{9} x.fx$
Clones	Grade frequencies									
PRIM 600	6	1	1	-	-	-	-	-	-	69
PR 107	3	3	1	-	1	-	-	-	-	63
Tjir 1	1	2	1	-	1	5	-	-	-	49
RRIM 612	1	4	2	1	-	-	-	-	-	61
GI 1	1	4	-	2	1	-	-	-	-	58
RRIM 501	1	3	2	-	-	-	2	-	-	53
GT 1	1	2	1	-	2	-	1	1	-	49
RRII 300	-	4	2	1	1	-	-	-	-	57
PB 235	1	2	1	1	1	1	-	-	1	48

progressively declined with the advancement of dry period and it reached PWP level during April and May. The study period did not receive any rainfall.

In the North Konkan region the rainy season is from the middle of June to September and the atmospheric preciptation is nil for more than seven months. Towards the second half of the rainless period high atmospheric heat load and vapor pressure deficits coupled with severe soil moisture stress created adverse conditions for growth of plants. It has been estimated that the annual water deficit in the region is around 1070 mm, whereas it is around 350 mm in the traditional rubber growing region (Ruber Research Institute of India, 1988).

Leaf water potentials recorded for the clones in different months are given in Table 2. In February, the clones formed three homogeneous groups for the morning hour ψ but in the afternoon the clones formed two groups and the values ranged from -2.04 MPa to -1.75MPa. In May, RRIM 600 with highest ψ(-0.68 MPa) in the morning was significantly different from others. The remaining clones formed two comparable groups. For the AN ψ the clones discerned into two groups. Afternoon ψvalues in both the months were comparable.

Water potential measurements, especially at predawn hours, are good indicators of plant moisture status and hence severity of stress conditions. Predawn measurements of the clones in this study, in general, were similar indicating that the plants were under moisture stress in February itself. The values noted should qualify for classifying the moisture status as severe stress because it has been reported that under good soil moisture supply, the lowest PD had ranged

Table 5. ***Comparison of stomatal performance with girth rankings of nine Hevea clones***

Clones	Stomatal performance I_{sp} Score	Rank	Growth performance (Feb. 91) Girth (cm)	Rank
RRIM 600	69	1	56.5	1
PR 107	63	2	50.8	4
Tjir 1	49	7	49.4	7
RRIM 612	61	3	53.2	2
GI 1	58	4	50.1	6
RRIM 501	53	6	53.1	3
GT 1	49	7	48.0	9
RRII 300	57	5	50.7	5
PB 235	48	8	48.8	8

Correlation coefficient between I_{sp} and girth is = 0.7933 (Significant at P<0.05)

from -0.41 to -0.63 MPa and the measurements obtained in this study are in agreement with the results reported earlier for similar stress conditions (Devakumar *et al.*, 1988; Chandrashekar *et al.*, 1990; 1993; Gururaja Rao *et al.* 1988; 1990).

Stomatal conductance values recorded for the clones are presented in Table 3. In February highest MN g_s noted was for RRIM 501 and the lowest for Tjir 1. The values ranged from 22 to 84 m moles $m^{-2}s^{-1}$. In May, the MN g_s of each clone was different giving maximum comparisons and the g_s values ranged from 12.5 to 123m moles $m^{-2}s^{-1}$. In general MN g_s values were higher compared to AN g_s values. The effects of stress conditions were clearly evident on g_s. Stomatal conductance rates were very low. It has been reported that under propitious environmental conditions, the g_s could be more than 400 m moles $m^{-2}s^{-1}$ (Bhaskar *et al.*, 1990; Chandrashekar *et al.*, 1990). Compared to those results, the values obtained in this study were very low. Inspite of these conditions the plants appeared to be doing satisfactorily (Chandrashekar, 1983; Chandrashekar *et al.*, 1990; 1993; 1994). This gives and indication that the drought conditions might not have resulted in cavitation of plant xylem and the meristematic tissues tolerate dessication. In a few clones g_s in May was higher than that of February. This could be due to the clonal, temperature and VPD differences existing in the months.

Computation of the index of stomatal performance (I_{sp}) and the rankings of the clones for stomatal and growth performance are presented in Table 4 and 5, respectively. RRIM 600 with highest I_{sp} and girth growth was the leading clone. PR 107 though had rank 2 in I_{sp} was 4th in girth rank. Tjir 1 had 7th rank both in I_{sp} and girth so also RRII 300 with rank 5. RRIM 501 with rank 6 in I_{sp} was third in girth growth. Like wise clones GT1 and PB 235 had lowest values both in I_{sp} and girth. Correlation coefficient between I_{sp} and girth was 0.7933 (significant at $P<0.05$).

Better growth observed in RRIM 600 may be indicative of possessing drought tolerance characteristics. The clones RRIM 612 and RRIM 501 though are comparatively low in I_{sp}, but are next to RRIM 600 in growth. This could have been mainly due to their better growth in monsoon periods (Chandrashekar *et al.* 1994).

From the results it is clear that there is clonal variability for drought tolerance. Significant correlation between I_{sp} and girth indicated that I_{sp} may be extended for juvenile identification of potential drought tolerant clones. Better maintenance of leaf water potential and stomatal performance alone might not have helped the leading clones in their better growth. A combination of morphological, physiological and biochemical characteristics might have given them the lead. Detailed studies are necessary to identify the candidate traits of drought tolerance.

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