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PHYSIOLOGY OF DROUGHT TOLERANCE OF HEVEA

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ABSTRACT

Clonal variations were evident in the responses to drought in terms of yield and associated physiological parameters. In the northern parts of the West Coast where normal drought period is long, the mean girth attained in four years was around 16 per cent less when compared to the girth attained in the traditional area. Water requirements of *Hevea* in different parts of the traditional area have been worked out using meteorological parameters and tentative schedules for irrigation are given.

KEY WORDS *Hevea*, drought tolerance, yield, water relations, growth

INTRODUCTION

The traditional rubber growing tract in India extends from Kanyakumari (Cape Comerin, 8°15' N) to Mangalore (12°52' N). Cultivation of Hevea is done on the hill slopes in the midlands on the western side of the Western Ghats and on the foot hills of the Western Ghats. Though the mean annual rainfall in the region is around 3000 mm, its monthly distribution is far from satisfactory (Table 1). Soil moisture deficits are experienced from December to May. From Table 1 it can be seen that though the total rainfall received in different regions are comparable, the distribution of rainfall becomes more and more unfavourable towards the northern parts of the West Coast. Thus in Dapchari (Thane District of Maharashtra State) where only trial plantations have been done, both the intensity and duration of drought are more when compared to Trivandrum or Kottayam. This is mainly due to the total absence of North-East Monsoon, Summer showers and early premonsoon showers in this region. The condition is intermediate in Mangalore region.

TABLE 1 Rainfall distributions in the traditional rubber growing regions and in non-traditional region (Dapchari below the Western Ghats)

Month	Rainfall (mm)				
	Trivandrum (8° 29' N)	Kottayam (9° 32' N)	Calicut (11° 15'N)	Mangalore (12° 52'N)	Dapchari (19° 58'N)
January	20.1	18.3	5.9	4.7	0.5
February	20.3	32.0	11.1	1.9	0.4
March	43.5	62.1	21.0	8.9	0.1
April	122.1	180.0	111.1	40.0	0.1
May	248.6	319.0	322.5	232.7	8.5
June	331.2	629.1	870.9	981.6	597.2
July	215.4	630.8	860.0	1058.6	935.8
August	164.0	416.8	404.9	576.9	544.4
September	122.9	303.5	215.0	267.0	426.5
October	271.2	304.1	290.4	205.0	93.5
November	206.9	221.0	140.0	70.6	9.0
December	73.1	53.9	29.9	18.2	0.1
Total	1839.3	3171.6	3281.8	3466.1	2616.1

* The data is mean of 30 years.

Incidence of unusual droughts are also now becoming more frequent even in the traditional area. Severe droughts were experienced in the traditional area dùring 1982-83 and 1986-87. Understanding of the drought effects and devising of agrotechniques are the major approaches to realise better productivity in the traditional area and to extend the crop to the extreme drought affected areas. The approaches made in RRII are

* Quantification of drought (soil and atmospheric).
* Quantifications of growth and yield reductions caused by drought.
* Quantifications of changes in physiological parameters associated with growth and yield under drought conditions.
* Quantifications of clonal differences in the above.
* Evaluation of dry farming techniques including irrigation in regions with more dry months.
* Evolving of screening techniques for parameters associated with drought resistance.

Some of the data collected with the above objectives are discussed in this paper.

MATERIALS AND METHODS

1. Soil Moisture Depletions Under Unusual Drought

The traditional rubber growing areas in the West Coast experienced an unusual and severe drought during 1986-87 mainly on account of early cessation of South-West and North-East Monsoons (Table 2). A survey was made in the month of March 1987 on soil moisture depletions at four locations within the same agroclimatic zone around Kottayam. The locations selected were RRII Experiment Station, Central Experiment Station (RRII), Harrisons Malayalam Estate (Cheruvally) and Malankara Estate. Soil moisture percentages were estimated at depths of 0-15, 15-30, 30-60 and 60-90 cm. Soil water potentials were calculated using soil moisture release curve worked out for oxisols (1).

2. Effeect of Drought on Growth

Girth recordings of 12 clones (4th year) planted in Central Experiment Station and Regional Research Station, Dapchari were regularly made. Plants in Dapchari were given life saving irrigations (15 litres/ plant/week) (Table 3).

TABLE 2 Monthly rainfall (mm) during 1986-87 in Kottayam.

Month	1986	1987
January	0.0	0.0
February	15.0	16.6
March	41.0	0.0
April	108.3	112.3
May	178.0	187.5
June	559.3	698.6
July	353.9	181.7
August	521.9	651.2
September	279.6	243.8
October	133.4	310.5
November	270.2	263.7
December	6.1	74.7
Total	2466.0	2750.0

TABLE 3 Mean girths (cm) attained in four years by different Hevea clones (1982 planting) in traditional (CES) and drought prone (Dapchari) regions below the Western Ghats

Clone	Location	
	CES	Dapchari
RRII 300	19.4	17.7
PB 235	21.9	15.9
GT1	17.8	16.8
RRIM 612	18.5	16.4
RRII 118	21.1	16.9
RRIM 703	21.7	13.7
Tjir1	21.8	15.7
RRII 105	18.8	12.9
RRIM 600	22.1	19.5
RRIM 501	15.3	15.5
PR 107	14.9	17.7
Gl 1	17.1	16.0

3. Effect of Drought on Yield

Monthly yield data were collected from the four locations where soil moisture depletions were studied (Table 4).

TABLE 4 Mean monthly yields (kg/ha) of different Hevea clones in the dry season (January-May 1987) and two wet seasons (June-December 1986 and 1987)

Clone	1986 Wet Season	1987 Dry Season	1987 Wet Season
RRIM 600	119	72	135
GT1	94	54	84
PB 235	109	56	125
Tjir1	41	31	80
G11	126	73	123
RRII 105	160	92	192
RRII 118	108	51	126

4. Effect of Drought on Physiological Parameters

Afternoon leaf water potentials of different clones were recorded in four locations mentioned earlier. The estimations were made using thermocouple psychrometer (Wescor Inc., USA) and the data presented are means of five observations. Diurinal changes in leaf water potential, stomatal resistance, transpiration, xylem sap speed, turgor pressure of latex vessels and latex solute potential were estimated in clones RRII 105 and RRII 118, drought tolerant and susceptible, respectively in terms of yield (2). The observations were made in the dry season of 1987. Using the above observations daily transpiration rates, transpiration coefficients etc. were worked out.

5. Prospects of Irrigating Hevea in Different Agroclimatic Zones of the Traditional Area

The potential evapotranspiration at Trivandrum, Kottayam and Calicut were worked out for five months (December to April) using meteorological data with various assumptions made (Table 5). The daily water requirements and the quantities of irrigation water and frequencies of irrigations were worked out with many assumptions (Appendix I).

TABLE 5 Mean daily water requirements, quantities of water per irrigation and the frequencies of irrigations required for Hevea in different parts of the traditional region during the dry season (December-April)*

Year of planting	Plant Coverage (%)	Irrigated area per plant (M^2)	Quantum of irrigation (l/T)	TRIVANDRUM Mean water requirement (l/T/d)	TRIVANDRUM Irrigation requirement (l/T)	TRIVANDRUM Frequency of irrigation (days)	KOTTAYAM Mean water requirement 1/T/d	KOTTAYAM Irrigation requirement (l/T)	KOTTAYAM Frequency of irrigation (days)	CALICUT Mean water requirement (l/T/d)	CALICUT Irrigation requirement (l/T)	CALICUT Frequency of irrigation (days)	KERALA STATE Mean water requirement (l/T)	KERALA STATE Irrigation requirement (l/T)	KERALA STATE Number of irrigations required	KERALA STATE Frequency of irrigation (days)
1	10	1.6	100.0	10.6	1143	13.1	11.0	1065	11.4	12.1	1528	10.1	11.2	1245	13.0(16.8)	11.5(8.9)
2	22	2.5	156.0	23.2	2782	8.4	24.3	2525	9.3	26.7	3557	6.6	24.7	2955	18.5(23.7)	8.1(6.3)
3	35	3.4	212.5	36.9	3094	10.3	38.6	3218	8.0	42.5	4808	6.6	39.3	3707	18.0(27.7)	8.3(5.4)
4	50	3.4	212.5	52.8	3735	8.5	55.2	4177	6.1	60.7	6420	5.0	56.2	4777	23.0(39.6)	6.5(3.8)
5	65	3.4	212.5	68.6	4710	6.8	71.6	5343	4.8	79.0	8270	3.8	73.1	6108	29.4(51.6)	5.1(2.9)
6	80	3.4	212.5	84.4	7080	4.5	88.2	7352	3.5	97.2	11000	2.9	89.9	8477	41.6(63.4)	3.6(2.4)
7 and above	90	3.4	212.5	95.0	8670	3.7	99.2	8683	3.0	109.4	12770	2.5	101.2	10041	50.0(71.4)	3.0(2.1)

* Values in the parenthesis indicate the number and frequency of irrigation, if no rainfall is received, respectively.

APPENDIX - 1

Assumptions made to work out water requirements, quantities of irrigation water and frequencies of irrigations

1. Rooting depth	: 50 cm
2. Available water	: 125 mm
3. Depletion of irrigation	: 50%
4. Number of plants/ha	: 400
5. Canopy area range from first year to maturity	: 10 to 90%
6. Area of basin/plant	
First year	: 1.6 M^2
Second year	: 2.5 M^2
Third year onwards Basin + silt pit per plant (3.0 x 0.5 x 0.3 M)	: 3.4 M^2
7. Effective rainfall	
First & Second year	: As in basin
Third year	: 35%
Fourth year	: 60%
Fifth year	: 80%
8. Water requirement calculated according to Blaney & Criddle model (Water requirements of crops, irrigation and drainage paper of FAO)	
9. Crop coefficient	: 1.0
10. In case of basin irrigation, basin should be mulched for initial three years.	

RESULTS AND DISCUSSION

The depleted soil moisture percentages and the calculated values of soil water potentials in the different locations studied are presented in Table 6. Growth data of different clones in Regional Research Station, Dapchari and Central Experiment Station, Kottayam are given in Table 3. The mean monthly yields of different clones in the wet seasons of 1986 and 1987 and in the dry season of 1986-87 were given in Table 5. The diurinal changes in various components of whole tree water relations for clones RRII 105 and RRII 118 and meteorological parameters are presented in Fig. 1 and 2. The clonal comparisons of various components are summarised in Table 7.

Data given in Table 6 shows that during the unusual drought of 1986-87 there was no available soil moisture upto 60 cm depth in most of the places. Moisture availability was very low even in 60-90 cm layer. The pre-dawn leaf water potentials of around -0.1 to -0.2 MPa indicate that the plants were drawing water from soil layers below 90 cm depth, where the soil water potentials are equal to that of pre-dawn leaf water potentials. Water stored in the 0-30 cm layer during the study on the diurinal changes resulted from two showers received during the fortnight before the observations and was not available to plant as evidenced from our other studies (unpublished).

Though initially almost all clones showed better growth in Dapchari due to irrigation as compared to the unirrigated controls at Central Experiment Station, by 1986 most of the clones showed lower girths in Dapchari (Table 3) (3). This might have happened due to the inadequacy of the irrigations given. The general decline in growth was around 16%. However, though statistically not analysed, growth of clones RRIM 501 and PR 107 were either equal or better. Absolute growth was highest for RRIM 600 both at Central Experiment Station and at Dapchari. The data indicates that it might be possible to select parents for evolving clones with better growth than even RRIM 600 in drought-prone areas.

During the unusual drought season of 1986-87, the yield drops in different clones were in the range of 36% (GT 1) to 61% (Tjir 1) when compared to the favourable wet season yield of 1987 (Table 4). Though the absolute yield of clone RRII 105 was high during the dry season the percent decline in yield was severe and was comparable to that of PB 235. In terms of percent decline clone GT 1 was superior. RRIM 600 and Gl 1 were of intermediate nature. Clones Tjir 1 and RRII 118 were inferior to RRII 105 and PB 235.

The afternoon leaf water potentials in various clones experiencing severe soil moisture stress ranged from -2.0 MPa to -3.5 MPa as compared to the wet season range of -1.2 MPa to -1.7 MPa (unpublished). Though RRII 105 showed drying of lower branches the leaves were found to maintain better moisture status (-2.3 to -2.5 MPa). Maximum drops were found in clone Tjir 1 (-2.6 to -3.5 MPa). For RRIM 600 it ranged from -2.0 to -2.9 MPa. The values were -2.5, -2.8, -2.8 and -3.0 MPa for clones RRIM 501, PB 235, GT 1 and RRII 118, respectively. The diurinal

TABLE 6 Soil moisture percentage and soil water potentials (bar) under different Hevea clones in the plantations in Kottayam and adjoining areas during the unusual drought of 1986-87.

Soil Depth (cm)	RRII	MALANKARA		CES			CHERUVALLY	
	Gl 1, Tjir 1 RRIM 501	RRIM 600	RRII 105	Gl 1 Tjir 1	RRII 105 RRII 118	PB 235	RRII 105 GT 1	RRIM 600
0-15	15.80 (<-15.0)	12.57 (<-15.0)	12.50 (<-15.0	12.45 (<-15.0	12.46 (<-15.0)	13.30 (<-15.0)	12.25 (<-15.0)	12.36 (<-15.0)
15-30	16.30 (<-14.0)	14.13 (<-15.0)	14.85 (<-15.0)	14.42 (<-15.0)	14.41 (<-15.0)	15.78 (<-15.0)	13.21 (<-15.0)	12.98 (<-15.0)
30-60	17.60 (-8.9)	18.03 (-8.0)	16.87 (-11.6)	16.17 (-15.0)	16.18 (-16.0)	16.04 (-15.0)	14.90 (<-15.0)	13.74 (<-15.0)
60-90	19.48 (-2.7)	18.42 (-6.6)	17.49 (-9.8)	17.55 (-8.2)	16.44 (-13.2)	16.92 (-11.3)	15.24 (-15.0)	14.94 (<-15.0)

TABLE 7 Yield, yield components (Initial flow rate, plugging index, rubber content), afternoon leaf water potentials, latex vessel turgor, stomatal resistance, transpiration, relative ratios of transpiration/potential evapotranspiration and cumulative xylem sap speeds in RRII 105 and RRII 118 during the dry season of 1987

Parameter	RRII 105	RRII 118	C.D.$_{0.05}$
Yield (g tree^{-1} tap^{-1})**	46.26	18.62	5.22
Initial flow rate (ml cm^{-1} min^{-1})**	0.106	0.081	0.009
Plugging index**	3.95	5.59	0.292
Rubber content (%)**	44.2	45.6	0.744
Afternoon leaf water potential (-MPa)**	1.88	2.42	0.265
Maximum latex vessel turgor (MPa)**	1.10	0.88	0.126
Minimum latex vessel turgor (MPa)**	0.30	0.17	0.126
Minimum stomatal resistance (s cm^{-1})^{NS}	2.16	1.82	-
Mean stomatal resistance (s cm^{-1})**	14.62	6.82	0.92
Transpiration (mm m^{-1} day^{-1})**	0.5797	1.08	0.091
Transpiration/PET**	0.110	0.242	0.026
Cumulative xylem sap speed (cm/12 h)**	135.97	72.34	6.64

** Significant at 1% error.

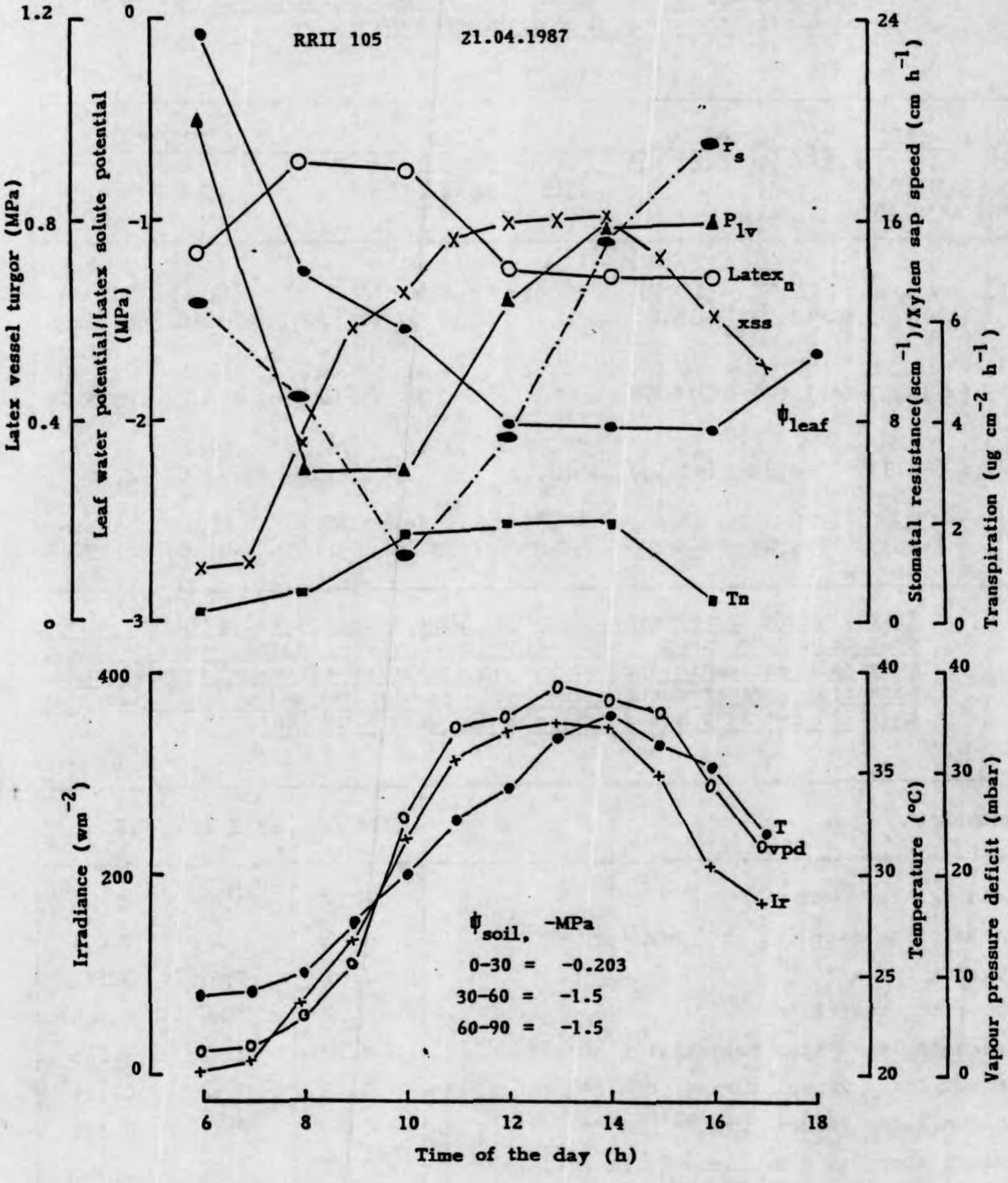

Fig. 1 Semi-diurnal changes in components of plant water relations (leaf water potential, ψ_{leaf} ; latex vessel turgor, P_{lv} ; latex solute potential, latex ψ_n ; xylem sap speed, XSS ; stomatal resistance, r_s and transpiration, T_n, and meteorological variables (ambient temperature, T ; vapour pressure deficit, vpd and irradiance Ir) in clone RRII 105 observed during moisture stress period of 1987.

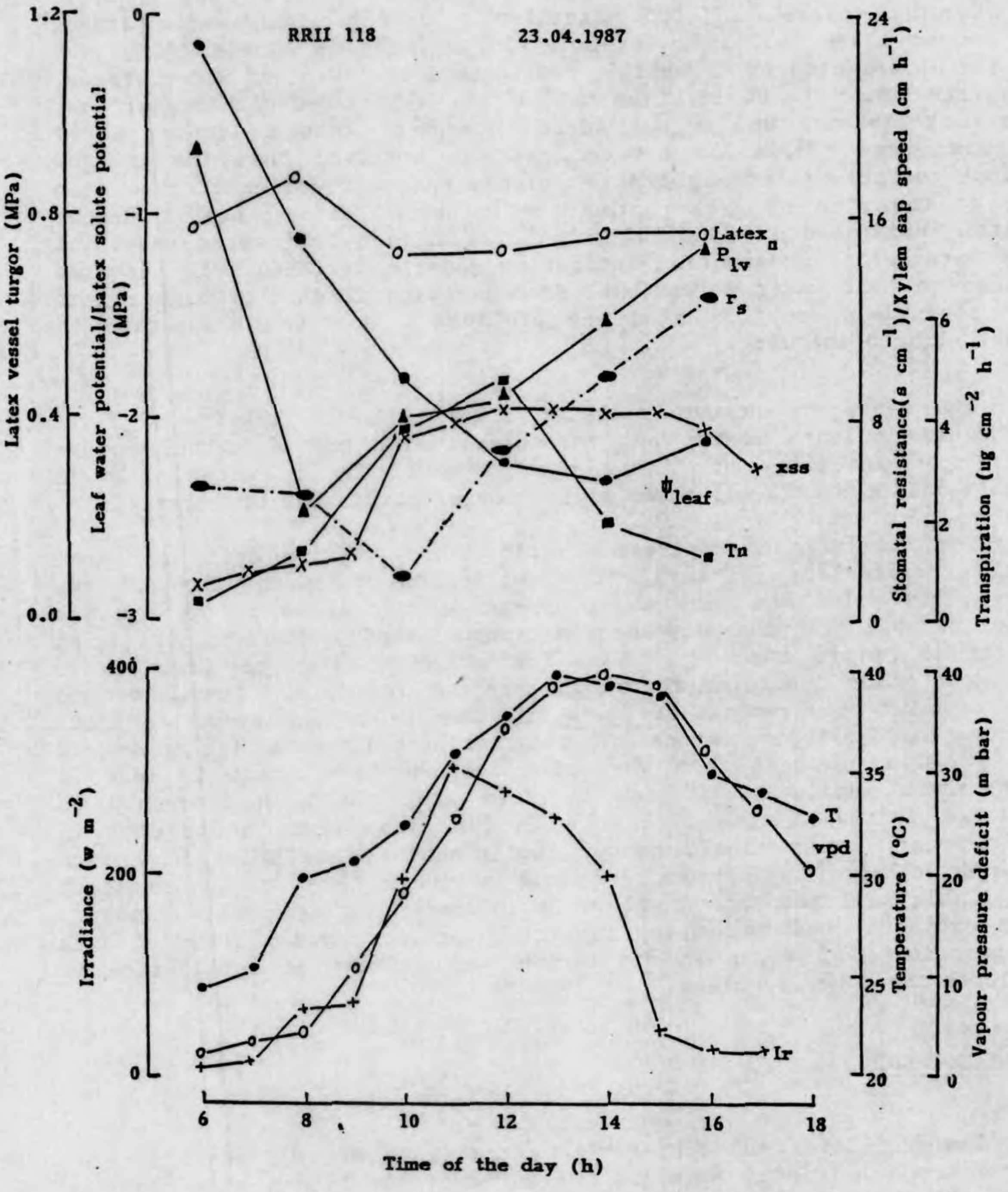

Fig. 2 Semi-diurnal changes in plant water relations and meteorological variables in clone RRII 118 observed during moisture stress period of 1987 (Details of the figure and the soil moisture levels are as in Fig. 1).

changes in components of plant water relations (Fig. 1 and 2) also indicate that clone RRII 105 maintains a better plant water status compared to clone RRII 118. Severe yield declines in clones Tjir 1 and RRII 118 as affected by drought is thus caused by low plant water status. The better water status in clone RRII 105 is associated with higher mean stomatal resistance and higher water recoupment rate as indicated by sap flow speed (Table 7). However, it was observed that the minimum stomatal resistance between the two clones were not different from each other at the time of peak photosynthetic hours. Maintenance of higher stomatal resistance in RRII 105 inspite of higher leaf water potential is an interesting observation indicating genetic variations in stomatal response to leaf water potentials. Branch drying inspite of higher leaf water potentials in this clone is probably a positive adaptation to drought (branch shedding).

The better recoupment rates in clone RRII 105, inspite of lower $\Delta\psi$ values indicate lower root resistance which may be either due to higher root intensity or higher root permeability to water. It is probable that the RRII 105 scion might induce better root proliferation.

The 'relative transpiration ratio' which now we call as transpiration coefficient (Table 5) is significantly different for the two clones. This value has been found to change from about 1.0 in the wet season to 0.2 in the dry season (unpublished). The transpiration coefficient can be used as a tool for studying water requirements of tree crops where lysimeter recordings are not feasible. The daily and seasonal water requirements of Hevea from the month of December to April in three agro-climatic zones of the traditional area are given in Table 5. It is evident from the data that the requirement is more in the northern latitudes. It can be seen that the mean frequency of irrigation increases from 11.5 days in the first year to 3.0 days in the 7th year (under closed canopy conditions). Since latex flow rate is turgor related, maintenance of soil moisture level at 50 per cent of available soil moisture or above is theoretically essential. However, the essentiality has to be experimentally proved. Availability of such huge quantities of water in dry months and methods of application in the slopes are other problems.

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