Growth Performance of *Hevea* in the Non-traditional Regions of India*

M.R. SETHURAJ, S.N. POTTY, K.R. VIJAYAKUMAR, A.K. KRISHNAKUMAR, P. SANJEEVA RAO, A.P. THAPALIYAL, T. MOHAN KRISHNA, G. GURURAJA RAO, D. CHAUDHURY, M.J. GEORGE, T.A. SOMAN AND J. RAJESWARI MEENATTOR

Rubber Research Institute of India, Kottayam, India

Abstract in Bahasa Malaysia

Di kawasan-kawasan penanaman getah tradisional di pantai barat daya India, skop untuk memperkembangkan lagi penanaman Hevea *kini telah kehabisan kerana sumber-sumber tanah yang terhad. Untuk mencapai tahap mampu diri, penanaman getah perlu diperkembangkan ke zon-zon bukan tradisional di mana terdapat berbagai rintangan persekitaran yang mempengaruhi pertumbuhan dan produktiviti.*

Di timur laut India, suhu rendah yang berpanjangan merupakan rintangan utama. Di barat dan timur India, kesesakan kelembapan tanah yang berpanjangan dan suhu-suhu ambien yang tinggi pada siang hari merupakan rintangan utama. Di kawasan-kawasan tinggi dalam zon tradisional di timur laut India, kesan-kesan suhu yang rendah, angin yang kencang dan aras yang tinggi menjadi rintangan utama. Usaha-usaha penyelidikan telah dimulakan dari awal tahun 1980an untuk mengenalpasti dan mengeluarkan klon-klon yang sesuai bagi lokasi-lokasi yang berlainan dan untuk memajukan kaedah-kaedah agro-pengurusan bagi mengurangkan kesan-kesan rintangan.

Dalam satu percubaan klon (1979) di Agartala di timur laut India, klon-klon RRIC 105, RRII 118, PB 235, RRIM 605 dan RRIC 52 mencapai ukuran lilitan batang yang boleh ditoreh dalam tempoh lapan tahun. Pertumbuhan yang paling tinggi kelihatan pada pokok-pokok RRIC 105 dan RRII 118. Dalam percubaan tahun 1982 di Agartala, perencatan pertumbuhan menyeluruh berbanding dengan pokok-pokok di wilayah tradisional adalah 20%. Dalam percubaan ini, klon-klon RRII 118, RRII 300 dan RRIM 600 didapati lebih baik dari yang lain. Di Assam (timur laut India), data untuk tiga tahun menunujukkan pertumbuhan yang baik bagi RRII 118, RRII 203, PB 235 dan RRIM 600. Perencatan pertumbuhan menyeluruh berbanding dengan pertumbuhan di kawasan-kawasan tradisional adalah 14% dalam tahun kelima mengikut data percubaan klon 1982 di Dapchari (barat India). Klon-klon RRIM 600, PR 107 dan RRII 300 menunjukkan prestasi yang lebih baik dari klon-klon lain di Dapchari. Di Tura (timur laut India, aras tinggi), prestasi pertumbuhan yang lebih baik kelihatan pada klon-klon RRII 118 dan RRII 203 dalam percubaan-percubaan pada tahun 1985 dan 1986. Di Mudigere (tropika, aras tinggi), perencatan pertumbuhan keseluruhan adalah 30% pada tahun kelima. RRIM 600 dan RRIM 703 menunjukkan prestasi yang lebih baik daripada klon-klon lain. Dalam percubaan klon dalam tahun 1982 di Wynad (tropika, aras tinggi), perencatan pertumbuhan adalah

*This paper was accepted but not presented at the Conference.

Proc of RRIM : Rubber Growers Conf. 1989, Malaysia.

26%. Klon-klon RRIM 600, RRIM 612 dan RRII 203 menunjukkan prestasi yang lebih baik daripada klon-klon lain. Pada keseluruhannya, prestasi klon yang paling popular, RRII 105 adalah rendah dalam keadaan-keadaan bukan tradisional.

Pokok-pokok di dalam polibeg di tapak semaian didapati lebih peka terhadap cuaca sejuk berbanding dengan pokok-pokok di ladang. Pokok-pokok muda PB 235 dan RRIM 605 didapati kurang meluruh daunnya.

Di wilayah tradisional, anggaran keperluan air purata tiap-tiap pokok matang adalah 100 liter/pokok/hari (400 pokok/ha) dalam musim kering. Kira-kira 26% – 41% air lagi diperlui di sektor-sektor barat dan timur. Di lembangan Dapchari, perairan pada kadar 200 liter/pokok/lima belas hari untuk pokok-pokok yang berumur tiga tahun memberi peningkatan yang marginal sahaja. Naungan sentuh didapati dapat menggantikan naungan biasa dengan berkesan bagi pokok-pokok tanaman ladang yang dibesarkan dalam polibeg dalam keadaan-keadaan di Dapchari.

Aspek-aspek lain seperti masa optimum untuk penunasan, corak-corak pembungaan, perubahan-perubahan diurnal dalam parameter-parameter fisiologi, dll. dibincangkan.

Abstract

In the traditional rubber-growing areas in the south-west coast of India, there is no scope for further expansion of *Hevea* cultivation due to limited land resources. To achieve self sufficiency, it became essential to expand rubber cultivation to different non-traditional zones where different types of environmental constraints which affect growth and productivity exist.

In north-east India, prolonged low temperature is the most limiting constraint. In western and eastern India, prolonged soil moisture stress and high ambient dry temperatures are the major limitations. In the high elevations of the traditional zone of north-east India, low temperature, high wind speed and high altitude effects are the major constraints. Research efforts were initiated from the early 1980s to identify and evolve clones suitable for different locations and to develop agro-management techniques to mitigate the stress effects.

In a clone trial (1979) at Agartala in north-east India, clones RRIC 105, RRII 118, PB 235, RRIM 605 and RRIC 52 reached tappable girth in eight years. Growth was highest in RRIC 105 and RRII 118. In a 1982 trial at Agarpala, the overall growth inhibition when compared to that in the traditional region was 20%. In this trial, clones RRII 118, RRII 300 and RRIM 600 were superior to the others. In Assam (north-east India), data for three years indicated better growth for RRII 118, RRII 203, PB 235 and RRIM 600. The overall growth inhibition compared to the growth in traditional areas was 14% by the fifth year from the 1982 clone trial data at Dapchari (west India). Clones RRIM 600, PR 107 and RRII 300 performed better than the others at Dapchari. At Tura (north-east India, high elevation), better growth performance was observed in clones RRII 118 and RRII 203 in both the 1985 and

1986 trials. At Mudigere (tropical, high altitude), the general growth inhibition was 30% by the fifth year. RRIM 600 and RRIM 703 performed better than the other clones. In the 1982 clone trial at Wynad (tropical, high elevation), growth inhibition was 26%. Clones RRIM 600, RRIM 612 and RRII 203 performed better than the others. In general, the performance of the most popular clone, RRII 105 was poor under non-traditional situations.

Plants in polybags in the nursery were found to be more sensitive to cold than plants in the field. Wintering of young plants was found to be less in PB 235 and RRIM 605.

In the traditional region, the estimated mean water requirement of a mature tree is 100 litres/tree/day (400 trees/ha) during the dry months. About 26% – 41% more water is required in the western and eastern sectors. In the Dapchari basin, irrigation at the rate of 200 litres/plant/fifteen days for three-year-old plants resulted in only marginal increase in growth. Contact shading was found to effectively replace conventional shading of field-planted plants raised in polybags under conditions in Dapchari.

Other aspects as optimum period for budding, flowering patterns, diurnal changes in physiological parameters, *etc.* are discussed.

Traditionally, cultivation of rubber is limited to the humid tropics within 10° north and south of the equator where the total rainfall, distribution of rainfall and ambient temperatures are suited for the growth of *Hevea brasiliensis*. In India, the traditional rubber areas extend upto 13°N, though moderate drought conditions are experienced annually in the northern parts. Altitude-wise, the limit for optimum growth is 450 m MSL. All the potential areas in the traditional zone have been brought under plantations and no further expansion is feasible. Being a net importer of natural rubber and considering the steady increase in internal consumption, steps were taken in the early 1970s itself to explore the possibility of extending rubber cultivation to the non-traditional regions in India. North-east India (22°N to 29.5°N) including the high elevation areas, the Konkan region of Western India (13°N to 20°N), the high elevation regions of the western ghats (8.5°N to 20°N) and certain parts of Madhya Pradesh, Orissa and West Bengal states (19°N to 27°N) were identified as marginally suitable for rubber cultivation with appropriate agro-techniques. The major environmental constraint in North-east India and under high elevation situations is the prolonged low winter temperature. In the lower latitudes *viz.* Konkan region, Orissa, Madhya Pradesh, *etc.* soil moisture deficit, high summer temperature and moderate winter temperature are the limiting environmental factors for optimum growth. Very limited information is available on clones and cultural practices to be adopted under low temperature conditions[1] and prolonged drought conditions[2,3]. There is little information on crop performance under high temperature stress of more than 40°C, combined effect of low and high

temperatures, drought, *etc.* Studies[4,5,6] on water requirement and water relations of *Hevea* under different agroclimatic conditions are also very few.

A number of field experiments were laid out in the past decade to identify genetic materials suited for the different agroclimatic conditions in the marginal non-traditional areas as well as to evolve agro-management practices. Effects of different agroclimates on the growth and physiological parameters of *Hevea* and results of drought and heat mitigation trials are discussed.

MATERIALS AND METHODS

The trials were carried out in different locations; a brief description is given below.

The traditional rubber-growing region of India is represented by the Central Experiment Station (CES) which is located 55 km east of Kottayam. The traditional area experiences a dry period of three to four months with slight diurnal and seasonal variations in temperature conditions. In North-east India, the Regional Research Station (RRS) Assam and RRS Tripura represent the sub-tropical low elevation with prolonged low temperature and high to moderate rainfall. Two stations at Tura in Meghalaya State; Ganolgre (600 m MSL) and Daraechikge (1100 m MSL) represent sub-tropical high elevation. Mullenkolly (840 m MSL) in Wynad district of Kerala and Poonoor in Calicut district are two nearby areas representing high and low elevations in the traditional region. The Regional Agricultural Research Station (RARS) Mudigere (100 m MSL) of the University of Agricultural Sciences (UAS) represent tropical non-traditional high elevation. The RRS Dapchari (20°N) in Maharashtra State represents the North Konkan region with a dry period of seven to eight months. The identified marginal areas in Orissa have soil moisture stress and low as well as high temperature stress situations.

The available meteorological data were collected from different sources *viz.* India Meteorological Department (IMD), UAS and from the observatories maintained by the Rubber Research Institute of India (RRII). The mean monthly water requirements were worked out as described earlier[6].

A clone trial comprising fifteen selected clones *(Table 1)* was laid out in a randomised block design (RBD) in the experimental farm of RRS Tripura in 1979. A multi-location clone trial comprising twelve clones *(Table 2)* was laid out in RBD in 1982 at four locations *viz.* RRS Tripura, RRS Dapchari, RARS Mudigere and CES. A clone trial was started in Assam in 1985 comprising ten clones with single-tree single-plot completely randomised design. In RRS Tura, two clone trials were set up in 1985 and 1986 respectively. There are ten clones each in the 1985 and 1986 trials *(Tables 3* and *4)*. The design is single-tree single-plot completely randomised. In 1981, a high elevation clone trial was set up at Mullenkolly. The trial consists of sixteen clones *(Table 5)* laid out in RBD. A similar trial was started at Poonoor estate as the control. An experiment on budding success in different months was done in RRS Tripura in 1987-88 using budwood from RRII 105. Visual scoring was made on

TABLE 1. GIRTH ATTAINED AND PERCENTAGE INCREMENTS OF DIFFERENT *HEVEA* CLONES AT RRS, TRIPURA

Clone	Girth (cm)				
	Feb. 1987	May 1987	Sept. 1987	Nov. 1987	Feb. 1988
RRII 5	45.00	46.39 (3.08)	48.57 (4.60)	49.52 (1.95)	50.70 (2.38)
RRII 105	48.19	49.74 (3.21)	52.09 (4.72)	52.90 (1.72)	53.60 (1.15)
RRII 118	54.04	55.93 (3.46)	58.56 (4.70)	59.94 (2.35)	60.65 (1.18)
RRII 203	48.58	50.60 (3.58)	52.93 (5.19)	54.28 (2.55)	54.70 (0.77)
RRIM 600	48.16	49.55 (2.88)	52.40 (5.75)	53.03 (1.20)	53.36 (0.62)
RRIM 605	50.69	52.25 (3.08)	54.40 (4.11)	55.48 (1.98)	55.98 (0.90)
RRIM 703	46.22	47.05 (1.79)	49.16 (4.48)	49.86 (1.42)	50.78 (1.68)
PB 86	43.86	45.54 (3.83)	48.27 (5.99)	49.89 (3.35)	50.33 (0.94)
PB 5/51	44.95	46.02 (2.38)	48.86 (6.17)	49.43 (1.16)	49.78 (0.70)
PB 235	52.18	43.60 (2.72)	56.04 (4.55)	57.39 (2.40)	57.88 (0.85)
Gl 1	40.24	41.21 (2.41)	73.72 (6.09)	44.15 (0.98)	44.62 (1.06)
GT 1	48.26	49.90 (3.41)	51.80 (3.79)	53.14 (3.16)	53.49 (0.09)
RRIC 52	50.20	52.75 (5.08)	54.52 (3.36)	56.57 (3.76)	57.48 (1.60)
RRIC 105	56.47	58.38 (3.38)	60.71 (3.99)	62.42 (2.81)	62.92 (0.80)
Her 1	42.45	43.67 (2.87)	45.26 (3.64)	46.15 (1.36)	46.60 (0.98)

Figures within brackets indicate percentage increase.

TABLE 2. GIRTH ATTAINED BY DIFFERENT *HEVEA* CLONES AT TRADITIONAL AND NON-TRADITIONAL ZONES IN 1986

Clone	Girth (cm)			
	CES	Dapchari	Tripura	Mudigere
RRII 300	19.4	17.7	18.9	12.3
PB 235	21.9	15.9	15.0	12.2
GT 1	17.8	16.8	15.4	12.9
RRIM 612	18.5	16.4	14.4	12.0
RRII 118	21.1	16.9	21.0	10.7
RRIM 703	21.7	13.7	16.8	13.4
Tjir 1	21.8	15.7	15.0	12.3
RRII 105	18.8	12.9	11.6	11.9
RRIM 600	22.1	19.5	17.8	13.1
RRIIM 501	15.3	15.5	12.9	10.9
PR 107	14.9	17.7	12.9	9.5
Gl 1	17.1	16.0	13.2	9.9

casualties due to the winter temperature in RRS Tura. Visual scoring on flowering was made in RRS Tripura. The mid-day stomatal resistance was measured from the plants in the trials at Mudigere and CES.

An experiment on the dry-farming method was set up in RRS Dapchari in 1986 on RRII 118 planted in 1983. The treatments were as shown in *Table 6*. In pit irrigation, water was added in pits (0.6 × 0.6 × 0.3 m) within the basin. In the contact shading treatment, the canopy surface was sprayed with 10% China clay solution containing 0.4% gum arabic as adhesive. Spraying was done in the beginning of summer. For the dew-catching treatments, coarse sand or granite chips were spread to a height of 15 cm in the basin (1.2 × 1.2 m area). Irrigation was carried out during the dry months.

The experiment on contact shading was conducted on clone RRIM 600 in RRS Dapchari. Plants raised in polybags were planted in the field in June 1987 and the treatments were given in the subsequent summer season. The treatments consisted of spraying the upper surface of leaves with 5%, 10% or 15% China clay solutions containing 0.4% gum arabic as adhesive. The stems were white-washed with China clay slurry. The control plants were shaded with baskets made of coconut leaves. The stems of the control plants were not white washed. All the treatments received irrigation. The layout of the experiment was RBD with five replications, with nine plants in each replication. Casualty and girth increments were recorded at regular intervals.

In all the above experiments, the quantities of fertilisers applied were as per the Board's recommendations.

TABLE 3. MEAN GIRTH AND GIRTH INCREMENT DURING DIFFERENT SEASONS IN TEN CLONES OF *HEVEA BRASILIENSIS* IN RRS, TURA (600 M MSL)

Clone	Average girth (mm)				Girth increment during different seasons (mm)			
	Feb. 1987	May 1987	Aug. 1987	Nov. 1987	Mar.–May 1987	Jun.–Aug. 1987	Sep.–Nov. 1987	Total
RRII 105	70.8	78.1	97.1	111.5	7.3	18.9	14.4	40.7
RRII 118	79.5	88.9	115.2	133.3	9.4	26.2	18.1	53.8
RRII 203	77.9	86.5	114.2	127.7	8.8	27.7	13.5	50.1
RRIM 600	72.5	80.8	105.5	118.5	8.3	24.7	13.0	46.0
RRIM 605	72.7	80.5	106.3	119.2	7.8	25.8	12.9	46.5
PB 86	70.8	77.1	95.7	106.8	6.3	18.6	11.2	36.1
PB 235	71.0	83.4	102.1	122.0	12.4	18.7	19.9	51.0
PB 5/51	58.1	65.0	83.7	95.4	6.9	18.7	11.7	37.3
Gl 1	65.6	73.0	93.3	103.0	7.4	20.3	9.7	37.4
GT 1	72.3	80.6	107.2	122.0	8.3	26.6	14.8	49.7

TABLE 4. MEAN GIRTH RECORDED FOR THE PERIOD, NOVEMBER 1986 TO NOVEMBER 1987 AT RRS, TURA (600 M MSL)

Clone	Mean girth (mm)					Girth increment during different seasons (mm)				Total
	Nov. 86	Feb. 87	May 87	Aug. 87	Nov. 87	Nov. 86–Feb. 87	Mar.–May 87	Jun.–Aug. 87	Sep.–Nov. 87	
RRII 5	17.1	17.4	22.3	40.0	43.5	0.2	5.0	17.6	3.5	26.4
RRII 105	18.3	18.8	24.4	45.5	51.5	0.5	5.6	21.1	6.0	33.2
RRII 118	19.6	19.8	27.8	51.1	58.6	0.2	8.0	23.3	7.5	39.0
RRII 208	21.2	22.3	33.5	53.6	59.5	1.0	11.2	20.1	5.9	38.3
RRIC 102	16.1	16.1	23.9	44.6	45.6	0.0	7.8	20.7	1.0	29.5
RRIC 105	15.8	16.3	21.0	42.8	45.2	0.5	4.8	21.8	2.4	29.4
PB 260	18.2	21.8	25.6	44.8	50.1	3.6	3.8	19.1	5.3	31.9
PB 310	14.8	14.8	19.8	40.7	47.4	0.0	5.1	20.9	6.7	32.6
PB 311	15.9	16.7	22.3	40.2	45.8	0.7	5.6	17.9	5.6	29.9
PCK 1	16.4	18.2	23.5	43.0	47.5	1.7	5.3	19.5	4.3	30.9

TABLE 5. GIRTH OF DIFFERENT *HEVEA* CLONES AT POONOOR (PLAINS) AND MULLENKOLLY (HIGH ELEVATION)

Clone	Girth (cm)		Inhibition (%)
	Poonor	Mullenkolly	
PB 28/59	40.93	30.77	24.82
RRII 203	46.80	32.16	31.28
PB 6/9	31.76	19.58	38.73
RRII 105	44.72	26.40	40.96
RRIM 612	43.91	32.12	26.85
RRIM 501	44.28	27.20	38.57
RRIM 605	39.74	26.68	32.86
Gl 1	35.15	27.78	20.96
PB 5/51	40.36	27.44	32.01
PR 107	36.08	26.62	26.22
GT 1	44.97	28.28	37.11
RRIM 600	37.32	33.46	10.34
RRIM 623	44.01	32.71	27.32
Tjir 1	37.75	29.75	21.19
LCB 1320	45.73	27.03	59.10
RRII 118	50.63	33.23	34.46
Mean	39.02	28.82	31.42

TABLE 6. GROWTH OF *HEVEA* UNDER DRY-FARMING METHOD AT RRS, DAPCHARI

Treatment	Girth (cm)			Girth increment (cm)	
	1986	1987	1988	1986–87	1987–88
Deep irrigation I (200 litres/15 days)	14.1	20.3	28.5	6.2	8.2
Deep irrigation II (200 litres/20 days)	13.9	19.9	27.7	6.0	7.8
Deep irrigation III (200 litres/25 days)	14.0	20.1	27.9	6.1	7.8
Pit irrigation I (50 litres/10 days)	13.8	20.6	27.5	6.8	6.9
Pit irrigation II (50 litres/15 days)	14.0	19.8	27.2	5.8	7.4
Pit irrigation III (50 litres/20 days)	13.6	19.1	26.4	5.5	7.3
Pitcher drips (5 litres/day) with organic mulch	13.8	19.4	26.5	5.6	6.9
Pitcher drips (5 litres/day) with polythene mulch	14.0	19.2	26.1	5.2	6.9
Dew-catching – Coarse sand	14.1	19.5	25.8	5.4	6.3
Dew-catching – Granite chips	13.4	19.8	26.5	6.4	6.7
Organic mulch with China clay spray	14.1	19.2	26.1	5.1	6.9
Control with mulching without irrigation	14.1	18.9	25.3	4.8	6.4

RESULTS

The prevailing meteorological conditions for different research stations or from the nearest approved meteorological stations are given in *Table 7.*

TABLE 7. METEOROLOGICAL DATA OF TRADITIONAL AND NON-TRADITIONAL RUBBER GROWING REGIONS OF INDIA

Region	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Chethackal (9° 22′N, 76° 50′E, 50 m)												
Max. temp. (°C)	31.9	32.7	33.4	32.8	31.4	29.2	28.4	28.6	29.3	29.9	30.4	31.1
Min. temp. (°C)	21.1	22.1	23.2	23.6	23.5	22.6	22.1	22.2	22.4	22.3	22.2	21.5
Rainfall (mm)	52	55	125	226	261	661	390	494	359	502	304	67
Mudigere (13° 5′N, 100 m)												
Max. temp. (°C)	27.0	29.6	31.3	31.0	29.3	23.3	22.6	22.1	24.3	25.8	25.8	26.2
Min. temp. (°C)	13.7	14.8	16.9	18.3	19.0	18.3	17.9	17.8	17.6	17.2	15.4	14.8
Rainfall (mm)	3	14	42	81	111	501	619	496	236	162	66	35
Dapchari (19° 58′N, 72° 45′E)												
Max. temp. (°C)	27.7	28.2	30.3	32.0	32.9	32.1	29.7	29.1	29.6	31.7	31.9	29.7
Min. temp. (°C)	16.8	17.5	21.0	23.9	26.8	26.4	25.1	24.8	24.3	23.0	20.0	17.01
Rainfall (mm)	0	0	0	0	9	597	936	544	427	94	9	0
Kamakhyanagar (20° 56′N, 85° 33′E)												
Max. temp. (°C)	27.7	30.5	35.2	38.9	40.3	36.3	31.2	31.1	31.6	31.0	28.7	26.9
Min. temp. (°C)	13.8	16.3	20.4	24.9	26.8	26.5	25.2	25.1	24.9	22.5	17.6	13.4
Rainfall (mm)	17	27	17	36	79	201	360	331	234	100	24	4
Guwahati (26° 11′N, 91° 45′E, 55 m)												
Max. temp. (°C)	24.0	26.3	30.2	31.6	31.0	31.5	32.1	32.3	32.1	30.5	27.7	24.9
Min. temp. (°C)	11.0	12.8	16.5	20.3	22.7	24.7	25.8	25.8	25.2	22.0	16.9	12.5
Rainfall (mm)	11	18	53	126	274	293	302	263	190	90	12	5
Agartala (23° 53′N, 91° 15′E, 200 m)												
Max. temp. (°C)	25.7	27.8	32.0	33.5	33.2	31.6	31.4	31.5	31.2	31.4	29.6	26.2
Min. temp. (°C)	10.4	12.6	19.0	21.8	22.6	24.7	24.6	24.6	23.8	21.3	16.1	11.6
Rainfall (mm)	4	19	62	185	307	348	232	303	270	150	41	11
Tura (25° 31′N, 90° 14′E, 370 m)												
Max. temp. (°C)	23.6	26.4	29.9	32.5	31.0	29.3	28.9	29.3	29.5	28.9	26.5	24.7
Min. temp. (°C)	12.3	14.9	18.7	22.1	22.9	22.7	23.2	23.3	22.7	20.3	16.3	13.5
Rainfall (mm)	12	8	72	131	402	739	709	559	462	250	18	1

In the traditional rubber-growing area, the rainfall varies from 1800 mm to 3500 mm with 105 to 139 rainy days. The mean air temperature varies from 22°C to 33°C with a seasonal range of 8.2°C to 15.2°C. The mean relative humidity varies from 71% to 80% with 7.0 h of sunshine/day, 2 – 11 km/h wind speed and the evaporation rate is 3.7 – 4.3 mm/day. At a planting density of 400 trees/ha, the water requirement varies from 12 litres to 100 litres/tree/day from the immature to the mature phase.

North-east Region

In the north-east region, the rainfall varies from 1600 mm to more than 3300 mm, distributed in 87 to 135 days. The mean air temperature varies from 19°C to 30°C with a seasonal range of 22°C to 23°C. The mean relative humidity varies from 76% to 82%. The low temperature of 3.8°C was recorded at Agartala. In addition to low temperature, the incidence of hail storm is another constraint in Tripura.

In the 1985 clone trial in Assam, clones RRII 118, RRII 203, PB 235 and RRIM 600 attained girths of between 19 cm and 20 cm by 1988. It was observed that 70% to 80% of growth was obtained during the period from June to November. Clones PB 5/51 and Gl 1 were found to be most affected by low temperature stress conditions.

The girths attained by different clones by 1987 and 1988 and the seasonal girth increment during the 1987 and 1988 period in the 1979 clone trial in RRS Tripura are given in *Table 1*. The maximum girth was attained in clones RRIC 105 and RRII 118. Clones PB 235, RRIC 52, RRIM 600 and RRIM 605 also showed good growth by attaining more than 50 cm girth by the beginning of 1987. Poor growth performance was observed in clones Gl 1 and Tjir 1. Girth increments were observed to be more during the period from February to September and there was a retardation of growth during the winter months.

Data on girth attained by different clones in the initial four years in the 1982 multi-location clone trial in RRS Tripura are presented in *Table 2*. The maximum girth was attained by RRII 118 followed by RRII 300 and RRIM 600. Girths of clones RRII 118 and RRII 300 were comparable to the girth attained by these clones in CES. Performance of clones RRII 105, RRIM 501, PR 107 and Gl 1 was not satisfactory. The overall growth inhibition was around 20% when compared to CES. Data on green budding and brown budding successes in different months in Tripura conditions are given in *Table 8*. It was observed that green budding was more successful than brown budding. In green budding more than 90% success was obtained in the months from February to June. The success was very poor during October, November and December. In the remaining months, the success ranged from 40% to 67%. In the case of brown budding, the maximum success was in the mouth of July (81%) followed by June (69%). The period from November to March was found to be unsuitable for brown budding. In the remaining months, the success ranged from 36% to 65%.

TABLE 8. MONTH-WISE PERCENTAGE SUCCESS OF GREEN AND BROWN BUDDING IN RRS, TRIPURA

Month	Success (%)	
	Green budding	Brown budding
April 1987	95.8	55.83
May	95.8	59.16
June	90.8	69.16
July	67.5	81.66
August	50.8	65.83
September	40.0	41.60
October	10.0	36.66
November	3.3	13.33
December	0	0.58
January 1988	45.0	–
February	97.0	–
March	98.0	–

In Tripura, the majority of the clones flowered during February and March. PB 86 and PB 5/51 showed early flowering. Clones RRII 118 and RRIM 600 flowered late.

North-east: High Elevation

The mean annual rainfall received in the Tura region is 3363 mm, the majority of the precipitation occurring in the months of May to October. The dry period extends from November to April. The monthly mean maximum temperature varies from 23.6°C to 32.5°C. The monthly mean minimum temperature varies from 12.3°C to 23.3°C. The winter season extends from November to February and within the dry period. In the 1985 clone trial of Tura *(Table 3)*, the maximum growth rate was found in clone RRII 118 followed by PB 235, RRII 203 and GT 1. Growth rates of clones PB 86, PB 5/51 and Gl 1 were very poor when compared to other clones. Data on the 1986 clone trial are presented in *Table 4*. Growth of clones RRII 208 and RRII 118 was found to be much more superior to that of other clones. Girthing was found to be the lowest in RRII 5. The maximum growth rates were observed during the period from June to August in both the trials of 1985 and 1986. Negligible growth rates were observed during the winter season in both trials.

ıer clones. Girthing was

The data on the percentage of plants in the different clones (1985 trials) which showed leaf shedding during the 1987-88 winter season is presented in *Table 9*. Leaf shedding was found to be least in clone PB 235, and highest in Gl 1. In clones PB 86, RRIM 600, GT 1, RRII 203 and PB 5/51, leaf shedding ranged from 60% to 71%; in the remaining clones *viz*. RRII 105, RRII 118 and RRIM 605, the range was 16% to 33%.

TABLE 9. PERCENTAGE OF PLANTS WHICH SHOWED WINTERING IN DIFFERENT CLONES AT RRS, TURA (600 M MSL)

Clone	Plants wintered (%)
RRII 105	33.33
RRII 118	30.30
RRII 203	61.36
RRIM 600	68.75
RRIM 605	15.78
PB 86	71.11
PB 235	4.54
PB 5/51	60.60
Gl 1	74.41
GT 1	67.44

In Tura, during the winter season of 1987-88, nearly 83% of the plants planted in polybags died of injury due to chilling, whereas in the field, where the same batch of budded stumps were planted, the casualty was only 9%.

Tropics: High Elevation

The total annual mean rainfall at Mudigere is 2366 mm. The majority of the rainfall is received during the period from June to October. The period from November to May is dry. The monthly mean maximum temperature varies from 31°C to 22°C. The monthly minimum temperature varies from 13.7°C to 19°C. Low night temperatures are experienced in the months from November to February. In general, temperature in the region is much below that of CES.

At Mudigere, growth inhibition by the fifth year of planting was observed to be around 30% when compared with performance at CES *(Table 10)*. However, clones RRIM 600 and RRIM 703 showed better performance compared to the remaining clones. Girths attained by clones Gl 1 and PR 107 were the lowest.

Data in *Table 11* show that the mid-day stomatal resistance is very high at Mudigere when compared to the values at CES. Clonal variation could also be seen in the stomatal resistances.

Data attained by the different clones by the sixth year at Mullenkolly and Poonoor are presented in *Table 5*. In the high elevation, the maximum girth was recorded by clone RRIM 600 followed by RRII 118 and RRIM 623. The growth rate of PB 6/9 was poor. The general growth inhibition in the high elevation was around 30% with the highest percentage of inhibition in LCB 1320, RRII 105, PB 6/9, RRIM 501 and GT 1. The minimum inhibition was observed in RRIM 600.

TABLE 10. GIRTH ATTAINED BY DIFFERENT *HEVEA* CLONES AT FIFTH YEAR IN TRADITIONAL AND NON-TRADITIONAL AREAS

Clone	Girth (cm)		
	CES	Dapchari	Mudigere
RRII 300	33.02	28.13	21.75
PB 235	29.72	26.02	21.60
RRII 105	30.88	18.66	19.95
RRIM 600	31.55	28.51	23.12
GT 1	27.79	26.37	21.83
PR 107	23.09	28.70	17.34
Gl 1	26.13	24.38	16.67
RRIM 501	24.33	26.07	20.06
RRII 118	32.18	26.36	20.05
RRIM 703	32.90	21.00	24.41
Tjir 1	33.10	26.00	21.10
RRIM 612	32.17	25.32	21.85
Mean	29.73	25.46	20.85

TABLE 11. STOMATAL RESISTANCE OF LEAVES OF *HEVEA* GROWN AT HIGH ELEVATION (MUDIGERE) AND IN PLAN (CES) DURING JANUARY 1987

Clone	Stomatal resistance (s cm^{-1})	
	Mudigere	CES
RRII 300	33.15	4.96
PB 235	25.15	5.06
GT 1	48.60	4.69
RRIM 612	43.19	5.51
RRII 118	15.68	2.91
RRIM 703	10.47	5.53
Tjir 1	29.06	3.77
RRII 105	14.07	3.24
RRIM 600	10.15	3.37
RRIM 501	11.23	2.29
PR 107	18.35	5.05
Gl 1	15.82	4.17

Konkan Region

The Konkan region of Maharashtra experiences a total rainfall of around 2500 mm in seventy-two to one hundred days. The mean air temperature varies from 22°C to 31°C with seasonal range of 9.9°C to 16.1°C. Extreme low and high temperatures of 8.3°C and 43.5°C were recorded. More than 80% of the total rain is concentrated between June and September and the dry period extends to more than six months.

In the 1982 multi-location trial, the overall growth depression at RRS Dapchari *(Table 10)* was around 14%. Clones PR 107, RRIM 600 and RRII 300 attained more than 28 cm girth. The girths attained by clones PR 107 and RRIM 501 at RRS Dapchari were more than that attained at CES.

Data on girth increments under various dry-farming treatments under Dapchari conditions are presented in *Table 6*. It was observed that the various treatments did not serve any substantial effects on growth. Among the treatments given, basin irrigation at the rate of 200 litres, once in 15 days was found to be more effective than the other treatments.

The observations made from the contact-shading experiment at Dapchari *(Table 12)* indicated that the number of casualties among contact-shaded plants was comparable to the casualties among plants shaded with coconut leaf baskets. The girth attained by contact-shaded plants was slightly more.

TABLE 12. EFFECT OF CONTACT-SHADING ON CASUALTIES AND GROWTH OF YOUNG *HEVEA* OF RRS DAPCHARI

Treatment	No. of casualties	Girth (cm)
Conventional shade (coconut leaf basket)	2	9.2
Contact shade – 5% China clay	1	9.6
Contact shade – 10% China clay	1	10.0
Contact shade – 15% China clay	1	10.3

Orissa

In Orissa, the annual rainfall varies from 1300 mm to 1700 mm with sixty-four to seventy-eight rainy days. The mean air temperature varies from 22°C to 33°C with a seasonal range of 14°C to 30°C. Extreme temperatures of 42°C to 48°C during the day and 4°C to 11°C during the night were recorded. The mean relative humidity is 59% to 77% and the wind speed is 3.5 km/h to 17.8 km/h. The estimated maximum water requirement is from 17 – 139 litres/tree/day in the various stages of growth. Because of the extreme climate, heavy casualties were observed in the 1987 and 1988 plantings in Orissa.

DISCUSSION AND CONCLUSIONS

Reviewing the performance of various clones in different locations representing various agroclimatic compositions, certain general conclusions can be drawn. In the north-east, by selecting the appropriate clones based on experimental results, growth comparable to that obtained in traditional areas can be attained inspite of the existence of a period of low temperature. The depression of growth during winter seems to have been made up due to total solar in-put at higher altitudes and better

distribution of rainfall. The observation that plants in the polybags showed more sensitivity compared to field plants perhaps indicate that roots are more sensitive during low temperature situations. The higher success recorded by green budding is advantageous for the preparation of advanced planting materials under the climatic situations existing in the north-east. The situations in high elevations in the north-east certainly depress growth to a varying extent depending on elevation and other edaphic factors. However, the possibility of cultivating rubber upto an altitude of 660 m has been demonstrated in our trials. The effect of high altitude on growth is similar in the tropical region as well.

In Western India though the rainfall is adequate, the prolonged drought and high temperature are the major constraints. Irrigation during the early years and water conservation methods would be required for successful cultivation of rubber in this region. In the absence of these additional inputs, the immaturity period will be extended by two to three years making the project uneconomic.

Of the many areas identified, Eastern India represented by Orissa has posed the maximum problems. Our trials so far do not indicate any bright prospects for large-scale rubber cultivation in the State. However, careful selection of areas in pockets taking into account the local climatic compositions may furnish some possibility of growing rubber. The Institute is making use of the remote sensing technique to identify such areas.

The need for extension of rubber cultivation to marginal areas to meet the ever-growing demand for natural rubber is recognised. By starting various field stations, the suitability of each state for the cultivation of rubber has been assessed critically. However, trials on suitable clones, fertiliser schedule, irrigation and other aspects are in progress and are not reported in this paper. It is expected that in a few years, the Institute will be able to identify suitable areas and bring out appropriate recommendations.

REFERENCES

1. JIANG, AILIANG (1984) A Geoecological Study of Rubber Tree Cultivation at High Altitude in China. *Proc. Int. Rubb. Conf. 1984*, 117.
2. PUSHPARAJAH, E. (1983) Problems and Potentials for Establishing *Hevea* under Difficult Environmental Conditions. *Planter*, 59, 242.
3. SETHURAJ, M.R. (1986) Physiology of Growth and Yield in *Hevea brasiliensis*. *Proc. Int. Rubb. Conf. Kuala Lumpur 1985*, 3.
4. HARIDAS, G. (1986) Streamflow Measurements in a Small Watershed to Estimate Evapotranspiration from a Stand of Rubber. *Proc. Int. Rubb. Conf. Kuala Lumpur 1985*, 670.
5. GURURAJA RAO, G., RAJAGOPAL, R., DEVAKUMAR, A.S., SANJEEVA RAO, P., GEORGE, M.J., VIJAYAKUMAR, K.R. AND SETHURAJ, M.R. (1988) Studies on Yield and Yield Components of *Hevea* Clones during Water Stress in 1987. *Proc. Int. Cong. Plant Physiol. New Delhi 1988* (in press).
6. VIJAYAKUMAR, K.R., GURURAJA RAO, G., SANJEEVA RAO, P., DEVAKUMAR, A.S., RAJAGOPAL, R., GEORGE, M.J. AND SETHURAJ, M.R. (1988) Physiology of Drought Tolerance of *Hevea*. *C.R. Coll. Expl. Physiol. Amel.* Hevea, *Montpellier, France 1988*, 269.