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EFFECT OF IRRIGATION ON GROWTH AND ESTABLISHMENT OF YOUNG RUBBER PLANTS IN A HUMID TROPICAL REGION OF INDIA

Radha Lakshmanan, Thomson T. Edathil*, T.R. Chandrasekhar* and C.P. Reghu*
Rubber Research Institute of India, Regional Research Station, Padiyoor, Kannur, Kerala, India
*Rubber Research Institute of India, Kottayam-686 009, Kerala, India

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In an experiment to study the growth response of young rubber during the initial three years to varying levels of irrigation, plant girth and girth increment were on par with irrigation at 1.2, 0.9 and 0.6 IW/CPE ratio and significantly superior to that of the control and irrigation at IW/CPE of 0.3. Growth showed a peak in April and August for the irrigated plants. Seasonal girth increments showed that growth during the period from June to November was higher than that during December to May. Irrigation at IW/CPE ratio of 1.2, 0.9, 0.6 and 0.3 during the period from December to May exhibited a girth increment that was 84, 67, 49 and 46 per cent higher than that of the corresponding girth increment observed during the monsoon season. In the unirrigated treatment this was only 38 per cent. A significant increase in RGR was observed for the treatments irrigated at IW/CPE ratio of 1.2 and 0.9 over that of the other treatments. Consumptive use and the ratio of consumptive use to pan evaporation were also worked out.

Key words: Girth, *Hevea brasiliensis*, Immature rubber, Irrigation, IW/CPE ratio, Relative growth rate.

INTRODUCTION

Rubber (*Hevea brasiliensis*) is predominantly grown in the tropics between 10 °S and 8 °N latitude where an equatorial monsoon climate prevails. It prefers an annual rainfall of 2000 mm or more, well distributed throughout the year with 125 to 150 rainy days and with no excessively wet or dry period (Vijayakumar *et al.*, 2000). Besides a high atmospheric humidity of 80 per cent with moderate wind, bright sunshine at the rate of 6h/day throughout the year with a maximum temperature of 29 to 34°C and minimum of 20°C are the other atmospheric parameters, which support congenial growth of rubber. Any deviation from these ideal conditions results in delayed maturity.

Lack of soil moisture and limited root development coupled with high temperatures are main factors limiting early tree growth. The adaptability of rubber plants to thrive in marginal areas with an annual water deficit of 200 to 350 mm has been reported (Moraes, 1977). Studies in Thailand, which has a marked dry season of six months, have indicated growth inhibition of rubber to the extent of 15 per cent (Saengruksowong *et al.*, 1983). Inhibition of growth in rainfed plants compared to that of the irrigated plants has been observed at Dapchari, India and irrigation at 50 per cent

Correspondence: Radha Lakshmanan (Email: radha@rubberboard.org.in)

of the estimated crop water requirements was reported to reduce the immaturity period from 10 years to 6 years (Vijayakumar *et al.*, 1998).

In dry regions growth inhibition of *H. brasiliensis* in the initial years could be overcome by life saving irrigation (Haridas, 1979). Irrigation during the summer season has been reported to enhance the growth and reduce the unproductive period of growth (Pushparajah and Haridas, 1977; Omont, 1982; Jessy *et al.*, 1994).

The northern region of Kerala is characterized by a prolonged dry spell of 4 to 5 months from December to May (NARP, 1989) with a cumulative water deficit ranging from 500 too 600 mm along with high temperatures. The region receives an average of around 3400 mm rainfall a year, 75 per cent of which is concentrated during the months of June to August. Besides, soil temperature in the surface layer will be in the range of 45 to 47°C during the month of March. Moisture stress during this period affects the growth and production of rubber.

Unlike rubber, in most other tree crops, irrigation is a recommended practice. Due to the highly undulating topography and consequent increase in cost of cultivation irrigation is generally not feasible for rubber. However, a study on the effect of adequate soil moisture on rubber growth especially during the water deficit periods would help in devising suitable agro-management techniques that help in build-up of soil moisture. For situations under which irrigation is economically feasible, a schedule could also be developed. The study reports the results of an irrigation trial wherein different soil moisture regimes were maintained by scheduling irrigation at varying IW/CPE ratios.

MATERIALS AND METHODS

The experiment was conducted during June 2000 to 2003 at the farm of the Regional Research Station, Padiyoor, Kannur District, Kerala (Latitude 11° 58' N; Longitude 75° 36' E) in an almost level field at an altitude of 50 m above MSL. The soil type is of sandy clay loam with pH 6.1, bulk density 1.3 g/cm^3, field capacity of 28.2 per cent and permanent wilting point of 17.5 per cent (gravimetric estimates).

Young bud grafted plants of rubber clone RRII 105 was planted at a spacing of 4.5 x 4.5 m with 25 plants per plot. The experiment was laid out in randomized block design with four replications. Two border rows were maintained as guard rows between the treatments.

Five moisture regimes were imposed at varying IW/CPE ratios of 0.3, 0.6, 0.9 and 1.2 along with an unirrigated control treatment. The depth of IW was fixed at 5 cm to schedule irrigation at 50 per cent of available soil moisture. The depth of rooting was fixed as 60 cm for the first year and 75 cm for the second and third year. The area of root zone to be wetted was taken as 60 x 90 cm (0.54 m^2) in the first year and 180 x 200 cm (3.6 m^2) for the second and third year. Quantity of water per irrigation was 27 L per plant in the first year, 180 L per plant in the second and third year and was applied in the plant basin.

Fertilizer was applied in two split doses in April – May and September – October as per the recommendations. Cover crop of *Pueraria phaseoloides* was also established in the interrow areas.

Girth of the plants at 150 cm above the bud union was recorded at monthly intervals from 16 plants in each plot after excluding the border plants and used to calculate the girth increments. Biomass was estimated from girth using the equation developed by Shorrocks *et al.* (1965) and relative growth rate (RGR) was calculated from biomass changes. Soil samples were collected before and after irrigation from the different treatments and soil moisture was determined by the gravimetric method.

In the first year, irrigation commenced from the last week of January and continued till the onset of monsoon. Girth of plants was recorded after 45 days of treatment imposition. During the second and third year irrigation commenced from December and continued till the onset of rains. Mulching and shading was adopted, as recommended. Approximately 10 kg of dried grass was used as the mulch material and was applied in the plant basins. Shading was provided to all plants during the first year with plaited coconut leaves. From the second year the brown bark of the main stem of the plants were whitewashed using lime.

The average of the weather data for four years from 2000 to 2003 is given in Table 1. The details of the total number of irrigation and the total quantity of water applied along with the effective rainfall received are given in Tables 2 and 3. Consumptive use (CU) of water was calculated from the soil moisture depletion date (Michael *et al.*, 1974). Effective rainfall was calculated based on the soil moisture status and the potential evapotranspiration rates (Dastane, 1974). Seasonal consumptive use was calculated by adding up the consumptive use values for each sampling interval. Consumptive use per day was worked out by dividing the total CU by the duration of the irrigation period. The ratio (kc) of consumptive use to evaporation from an evaporation pan was also worked out.

RESULTS AND DISCUSSION

Weather

Maximum temperature ranged from 34 to 37°C during December to May with March showing the highest (36.6°C). The highest maximum temperatures recorded were 40°C (March 21, 2002) and 40.4°C

Table 1. **Mean weather data for 2000 to 2003 (4 years)**

Month	Temperature (°C)		Relative humidity (%)		Sunshine hours	Evaporation (mm)	Wind speed (km/h)	Total rainfall (mm)	No. of rainy days
	Max.	Min.	I	II					
Jan	34.8	19.5	82.6	38.9	8.1	4.3	2.1	16.0	1.0
Feb	35.2	20.8	87.8	43.6	8.2	4.7	2.5	3.0	0.8
Mar	36.6	22.0	86.6	43.1	8.6	5.7	3.1	3.5	0.3
Apr	35.5	23.5	89.2	54.4	7.7	4.9	2.6	140.0	7.0
May	33.9	23.4	90.3	61.5	6.6	4.4	2.6	142.5	10.8
June	30.6	22.3	94.3	77.6	2.6	2.4	1.6	807.9	24.3
July	28.9	22.1	94.2	79.1	2.6	2.3	1.8	761.8	26.8
Aug	28.9	22.1	93.4	78.8	2.9	2.2	1.7	646.1	22.5
Sept	31.3	21.9	92.5	69.1	5.9	3.3	1.8	180.4	10.3
Oct	31.4	21.8	94.0	67.7	4.9	2.7	1.3	515.9	15.3
Nov	33.7	21.1	90.7	52.8	7.6	3.3	1.4	92.5	3.0
Dec	33.9	18.3	79.5	39.3	7.9	3.6	1.7	31.0	0.3

Table 2. **Number of irrigations given for the different treatments**

Year	Treatment IW/CPE	Dec	Jan	Feb	Mar	Apr	May	Jun*	Total No. of irrigations
2000 to 2001	1.2	-	1	2	4	2	2	-	11
	0.9	-	1	2	3	1	1	-	8
	0.6	-	1	1	2	1	1	-	6
	0.3	-	1	-	1	1	-	-	3
2001 to 2002	1.2	-	1	3	4	3	1	-	12
	0.9	-	1	2	3	2	1	-	9
	0.6	-	1	2	2	1	-	-	6
	0.3	-	1	1	1	-	-	-	3
2002 to 2003	1.2	2	3	3	4	3	2	1	18
	0.9	1	3	2	3	2	1	1	13
	0.6	1	2	1	3	2	1	-	9
	0.3	1	1	-	2	-	1	-	5

* Irrigation continued till June 12th due to late commencement of monsoon rains

Table 3. **Quantity of irrigation water applied and effective rainfall**

Treatment	2000 – 2001 (Jan-May)			2001 – 2002 (Dec – May)			2002-2003 (Dec-June)*		
	Irrigation water (mm)	Effective rainfall*	Total water (mm)	Irrigation water (mm)	Effective rainfall*	Total water (mm)	Irrigation water (mm)	Effective rainfall*	Total water (mm)
1.2	550	186.6	736.6	600	121.9	721.9	900	143.9	1043.9
0.9	400	191.9	591.9	450	112.0	562.0	650	200.3	850.3
0.6	300	230.0	530.0	300	181.2	481.2	450	197.8	647.8
0.3	150	257.8	407.8	150	188.9	338.9	250	204.8	454.8
Unirrigated	50	321.9	371.9	50	188.9	238.9	50	257.3	307.3

* Effective rainfall for the period of irrigation

(March 25, 2003). The highest value of evaporation (5.7 mm/d) and maximum wind speed (3.1 km/h) were also recorded in March. Atmospheric humidity was relatively low during the period from December to April. The weather conditions experienced during the period from December to April was in general the least congenial for active growth of rubber.

Table 4. **Effect of irrigation on stand establishment (% vacancy)**

Treatment	Vacancy (%)		
	June 2001	June 2002	June 2003
IW/CPE 1.2	7.8	7.8	4.7
IW/CPE 0.9	4.7	7.8	6.3
IW/CPE 0.6	14.1	15.6	9.4
IW/CPE 0.3	12.5	18.8	14.1
Unirrigated	12.5	26.6	23.4
SE	3.4	5.76	5.03
CD (P≤0.05)	NS	NS	NS

Plant establishment

Irrigation during summer months increased the plant survival and reduced vacancy (Table 4). Plant establishment was higher in the frequently irrigated treatments compared to unirrigated and less frequently irrigated, though the differences observed were not significant. Irrigation at IW/CPE ratios of 1.2 and 0.9 reduced the plant loss to an extent of 70 to 80 per cent over the unirrigated plots. The vacant plant points were again replanted in June 2001 and 2002.

Girth

The effect of irrigation during the first year of planting did not indicate any significant changes in plant girth among the treatments (Table 5). This could be because of the frequent showers received during the dry season. The total rainfall received was 97.7 mm during the months from December 2000 to February 2001. Rains again commenced from April with a total rainfall of 143.7 mm. March was the only dry month. The plants being adequately mulched and shaded, the possibility of build-up of moisture stress during the first year of growth could have been minimal. This is indicated by the fairly good growth of unirrigated plants, though the girth values were lower than that of the irrigated plants. No significant reduction in girth of plants was observed during the first year of growth.

In the second and third year, plants irrigated at 1.2, 0.9 and 0.6 IW/CPE ratios maintained higher girth values and were significantly superior to that of the lower level of irrigation at 0.3 IW/CPE and the unirrigated treatments. Irrigation at 0.3 IW/CPE and the unirrigated control plots were on par with respect to girth. The positive influence of irrigation on girthing of the plants was more evident during the third year of growth compared to the second. Plants irrigated at IW/CPE ratio of 1.2 exhibited a girth increase of 1.7 cm over that of the unirrigated control plants in the second year of growth while during the third year the increase was to the extent of 4 cm.

Table 5. **Effect of irrigation levels on plant girth and girth increment**

Treatment	Girth (cm)			Girth increment (cm)		
	March 2001	June 2002	June 2003	March 2001 to June 2002 (second year)	June 2002 to June 2003 (third year)	March 2001 to June 2003
IW/CPE 1.2	3.74	9.84	16.87	5.91	7.22	13.20
IW/CPE 0.9	3.92	9.44	16.02	5.73	6.64	12.32
IW/CPE 0.6	3.71	10.38	17.00	6.14	6.80	12.77
IW/CPE 0.3	3.78	8.88	13.65	4.94	5.26	9.96
Unirrigated	3.54	8.19	12.71	4.80	5.45	9.51
SE	0.04	0.25	0.52	0.33	0.31	0.49
CD ($P \le 0.05$)	NS	0.8	1.52	NS	0.96	1.53

Girth increment

No significant difference in girth increment (Table 5) was observed between the different levels of irrigation and unirrigated plants during March 2001 to June 2002. Girth increment for the period from June 2002 to June 2003 was significantly higher at IW/CPE ratio of 1.2 and was on par with that of plants irrigated at IW/CPE ratio of 0.9 and 0.6. The same was the case for the girth increment from March 2001 to June 2003. The girth increment for the unirrigated treatment and that irrigated at IW/CPE of 0.3 were on par and significantly less than the other treatments.

The monthly variations in girth increment are indicated in Figure 1. In general, the plants exhibited a peak in growth in the months of April and August and the increase being higher for the irrigated treatments. The trend in growth observed was similar during the second and third year. Girth increment showed a decline for all the treatments in the month of March. The decline in girth was more for the unirrigated and the less frequently irrigated treatments. This can be attributed to the shrinkage of plant tissues due to the high temperature and high vapour pressure deficits leading to stress like conditions during the month. Chandrasekhar *et al.* (1996) reported a reduction in girth ranging from 0.2 to 0.5 cm for 6 to 7 year old rubber trees under dry conditions of Dapchari (Maharashtra). However, with the onset of summer showers and a slight improvement in weather conditions, leading to restoration of turgor lost during the proceeding months of February and March, growth picked up and a spurt in growth was observed in April. The frequently irrigated treatments showed as increased in girth increment ranging from 38 to 51 per cent over that of the unirrigated treatments. The increase in girth increment with irrigation at 0.3 IW/CPE was 21 per cent over that of the unirrigated plants during April. By May and June the growth rate declined.

A second period of increased growth was observed from July to September with the peak in August. During this period the maximum air temperature was around 30 ^{0}C and there was no soil moisture deficit. Hence even with the available lower levels of sunshine hours growth picked up and reached the maximum in August. The low vapour pressure deficit during this time helped in maintaining high turgidity of cells, congenial for cell division, elongation and expansion.

The observations on seasonal girth increment in plants indicated that growth was more, in general, during June to November than in December to May. Also during the period from June to November the increase in growth observed from July is maintained for a longer duration and continued till September with a slight decline from the peak in growth in August (Fig. 1).

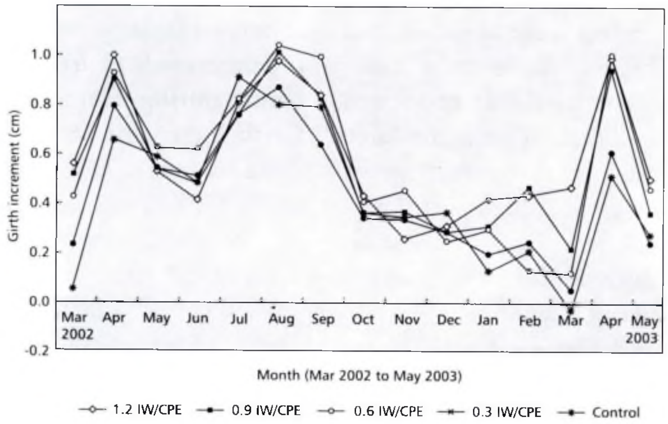

Fig. 1. Monthly variations in girth increment

With irrigation the girth increment for the period from December to May could be increased significantly. For the period from December to May irrigation at 1.2 IW/CPE exhibited a girth increment that was 84 per cent of the corresponding girth increment observed during the preceding season of June to November. In the case of the treatments with irrigation at IW/CPE ratios of 0.9, 0.6 and 0.3 it was 67, 49 and 46 per cent respectively. The girth increment observed in the summer months for the unirrigated treatments was only 38 per cent of that obtained during the preceding season of June to November. This indicates that during the period from December to May the growth of plants was limited by soil moisture availability. This coupled with adverse atmospheric conditions such as high air and soil temperature, together with the longer sunshine hours per day, high wind speed and high vapour pressure deficits limits the plant growth during this period. Also for the period from December to May the increase in growth observed in the month of April lasts for a short period only and declines by May.

Data on total plant biomass (Table 6) was also significantly higher in the treatments irrigated at IW/CPE ratios of 1.2, 0.9 and 0.6 over that at IW/CPE of 0.3 and the unirrigated plants. Leaf area and canopy size was also found considerably reduced in the control plants (data not presented). Seasonal changes in RGR (Table 6) for the dry and wet season indicated higher RGR for the irrigated treatments. RGR was significantly higher for the frequently irrigated treatments at IW/CPE of 1.2 and 0.9 than that irrigated less frequently and the control plots during the dry months from December to May 2002. A significant increase in absolute growth and relative growth rate during the dry season in the plants irrigated at 1.00 ET_c was reported by Mohankrishna *et al.* (1991) although the photosynthetic rate that could be attained was only 50 per cent of that during the wet season under Dapchari conditions. In the succeeding wet season from June to November 2002 the treatments irrigated the previous summer maintained higher RGR than the unirrigated, though the differences were not statistically significant. A general decline in RGR was noticed during the summer (December to May 2003) for all the treatments compared to that of the previous seasons. However, the treatment irrigated at IW/CPE of 1.2 and 0.9 maintained a significantly higher RGR over that of the other treatment and control which were on par with each other.

Table 6. **Effect of irrigation levels on plant biomass and seasonal RGR**

Treatment	Plant biomass (kg/plant)			RGR (g/kg/month)		
	March 2001	June 2002	June 2003	Dec-May 2002	Jun – Nov 2002	Dec-May 2003
IW/CPE 1.2	0.12	1.59	7.01	237.9	162.0	100.6
IW/CPE 0.9	0.12	1.45	6.20	220.1	177.2	85.5
IW/CPE 0.6	0.14	1.81	7.11	198.5	178.8	69.6
IW/CPE 0.3	0.12	1.22	4.07	174.3	155.4	61.9
Unirrigated	0.10	0.99	3.27	143.9	136.3	60.4
SE	0.01	0.1	0.46	10.8	16.4	4.9
CD ($P \leq 0.05$)	NS	0.32	1.42	33.4	NS	15.1

Consumptive water use

The consumptive use (CU) of water by plants during the dry months of 2001-02 (December to May, 15) and 2002-03 (December to June, 12) is given in Table 7. CU in the most frequently irrigated treatment went up to 4.2 and 4.6 mm/day while in the unirrigated treatment this was only 1.4 and 1.8 mm/day during the second (2-year old) and third year (3-year old) of study respectively. Monteny *et al.* (1984) observed that rubber plantations releases 4 to 6 mm of water vapour into the atmosphere when the soil moisture is adequate and only 2 to 4 mm when it is inadequate. The ET of two year old rubber plants (lysimetric study) was reported to be 4.97 mm per day during the summer season (Jessy *et al.*, 1992). The mean daily ET of young rubber grown in a glasshouse experiment varied from 2.1 to 6.9 mm per day and under field conditions this was found to be 4.4 mm per day when averaged over 21 months (Haridas, 1980).

The ratio of consumptive use to evaporation from an evaporation pan (E pan) was also worked out (Table 7). The unirrigated plot recorded the lowest value of 0.29 and 0.39 while the most frequently irrigated plot recorded a value of 0.86 and 0.99 during the summer months of the second and third year respectively, all the values being slightly higher in the third year.

Table 7. **Consumptive water use during summer by rubber plants in second and third year**

Treatment	Seasonal CU (mm)		CU (mm/day)		Ratio (CU/E_{pan})	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
IW/CPE 1.2	698.1	883.9	4.2	4.6	0.86	0.99
IW/CPE 0.9	561.9	778.0	3.4	4.0	0.69	0.88
IW/CPE 0.6	476.8	584.5	2.9	3.0	0.59	0.66
IW/CPE 0.3	330.7	430.2	2.0	2.2	0.41	0.49
Unirrigated	236.3	351.4	1.4	1.8	0.29	0.39

CONCLUSION

Irrigation is found to be beneficial in maintaining increased growth of rubber in the summer months. Plant girth and girth increment with irrigation at IW/CPE ratios of 1.2, 0.9 and 0.6 were found to be on par and significantly superior to irrigation at lower levels and unirrigated treatments. Hence irrigation at IW/CPE ratio of 0.6 can be recommended for optimum growth of rubber plants that are mulched till the third year of growth. Irrigation at IW/CPE ratio of 0.6 corresponds to an irrigation interval of around 12 to 14 days during the peak summer months. Irrigation with 27 L of water per plant for a basin area of 0.54 m^2 during the first year of planting and with 180 L of water per plant for a basin area of 3.6 m^2 during the second and third years was found to be sufficient for plant growth. Consumptive use was found reduced by more than 50 per cent in the unirrigated treatment over that at IW/CPE of 1.2 and 0.9.

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