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# AN ANALYSIS OF GROWTH AND DROUGHT TOLERANCE IN RUBBER DURING THE IMMATURE PHASE IN A DRY SUBHUMID CLIMATE

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## SUMMARY

An experiment with the objective of evaluating the performance of 15 clones of rubber (*Hevea brasiliensis*) was conducted in the Konkan region of Western India. The clones under evaluation were RRII 5, RRII 6, RRII 105, RRII 208, RRII 308, RRIC 52, RRIC 100, RRIC 102, RRIC 105, RRIM 605, PB 260, PB 310, PB 311, PR 255, and PR 261. The region is a trial environment for the crop and experiences more than seven rainless months and severe drought in the summer months. Data on monthly girth growth were collected for six years from a trial with randomized block design. The growth of clones in terms of monthly girth increment growth (GIN, cm month$^{-1}$) seasonal mean girth increments (MGIN, cm season$^{-1}$) and mean relative increment rates (MRIR, mm cm$^{-1}$ season$^{-1}$) as well as annual MGIN (cm a$^{-1}$) and MRIR (mm cm$^{-1}$ a$^{-1}$) was studied. Correlation analysis was performed to understand the effect of seasonal growth on the final growth. At the beginning of the study, the largest girth noted was for the clone RRII 6 (22.5 cm) followed by RRII 208 (22.0 cm). PR 261 with a girth of only 14.2 cm was the least vigorous among the clones. A large portion of the growth occurred in the wet season only. During the dry season the growth rates of the clones declined substantially and decreases in girth ranging from 0.2 cm to 0.5 cm were noticed in most of the clones. At the end of the study period the largest girth observed was for clone RRII 208 (49.3 cm) and the lowest for PR 261 (39.3 cm). The highest proportion of tappable trees noted was for clone RRII 208 (52.4%) and the lowest for PR 261 (2.7%). The pooled average of tappable trees was only 17.5%. The data revealed that the immaturity period for *Hevea* in the region will not be less than 9 years under rainfed conditions. From the analysis based on the final girth it was concluded that clones RRII 208, RRIC 52, RRII 6, RRIC 100 and RRIC 102 are more tolerant to drought while RRII 105, RRIC 105, RRII 5, RRIM 605, PB 310, PB 260, PB 311, PR 255, RRII 308 and PR 261 are less tolerant. The results of correlation indicated that by analysing the growth, potentially drought-tolerant clones can be identified.

## INTRODUCTION

Rubber (*Hevea brasiliensis*) is traditionally cultivated in India in a narrow tract of land extending from latitude 8 to 12°N in the Western Ghats. All the potential areas in the traditional region have been brought under rubber plantations and further expansion is not feasible. To bridge the widening gap between production and consumption, steps were taken in the early 1970s to explore the possibilities of extending *Hevea* cultivation to less congenial but potential areas (Sethuraj *et al.*, 1989). One of the regions selected for the purpose was the Konkan region of

Western India (15–20°N). In this region high summer temperatures and severe soil moisture deficits are the important constraints curtailing the growth and productivity of the crop (Sethuraj et al., 1989; Chandrashekar et al., 1990; 1994; 1996; Mohankrishna et al., 1991). Sanjeeva Rao et al. (1993), using a climatic index, have classified the region as conditionally suitable for *Hevea* cultivation. As in many tree crops, girth growth is the most important external manifestation of growth in *Hevea* that can be related directly to the accumulation of dry matter and this reflects the fraction of growth remaining after respiration. Genotypic differences do exist for growth performance in a given environment.

In *Hevea* the stem girth of the trees is the most important evaluation parameter based on which the degree of maturity of the plantation is decided for harvesting latex, the product of commercial importance (Sethuraj and George, 1980; Paardekooper, 1989). Ideally, a rubber plantation is considered mature and tappable if 50–70% of the trees have attained a girth of 50 cm at a height of 1.25 m (Sethuraj and George, 1980; Paardekooper, 1989). The time a plantation takes to attain maturity is also important because it determines how long farmers will have to wait for income to be generated from their plantations. Growth performance analysis can provide useful insights into the clonal differences in growth performance and its relationship with the seasonal growth and immaturity period. Though some specific information is available about the growth and yield of the crop in the region (Chandrashekar et al., 1990; 1993; 1994; 1996; Mohankrishna et al., 1991) information on the performance of the immature crop is lacking. No attempt has been made hitherto to analyse the immature growth of *Hevea* based on monthly girth observations of trees either in a traditional or a non-traditional region. The objective of this study is to report the growth, drought tolerance, immaturity period and the relationship between seasonal growth and overall performance in 15 clones of *Hevea* during their immature phase in a dry subhumid climate in India.

## MATERIALS AND METHODS

### *Study location and site features*

The study was conducted at the Rubber Research Institute of India's Regional Research Station at Dapchari (lat 20°04′N, long 72°04′E, altitude 48 m asl) in the Thane district of Maharashtra State. The experimental site of two blocks is slightly undulating with the slope facing west. The third block is located at a slightly higher location where the site is almost flat. The soil is of clay loam type with pH 6.3 to 6.5. It is 12% coarse sand, 22% fine sand, 28% silt and 38% clay (Karthikakutty Amma et al., 1989).

### *Planting material and experimental layout*

A trial was laid out in 1985 to evaluate the performance of 15 clones of *Hevea* in North Konkan. A large number of clones were available for inclusion in the experiment, but information as to where they would perform best was lacking. Therefore, the clones were selected based on their performance in the traditional

Table 1. Clones of rubber evaluated in the Konkan region.

| Clone | Parentage | Country |
|---|---|---|
| RRII 5 | Primary clone | India |
| RRII 6 | Primary clone | India |
| RRII 105 | Tjir 1 × Gl 1 | India |
| RRII 208 | Mil 3/2 × AVROS 255 | India |
| RRII 308 | Gl 1 × PB 6/50 | India |
| PR 255 | Tjir 1 × PR 107 | Indonesia |
| PR 261 | Tjir 1 × PR 107 | Indonesia |
| RRIM 605 | Tjir 1 × PB 49 | Malaysia |
| PB 260 | PB 5/51 × PB 49 | Malaysia |
| PB 310 | PB 5/51 × RRIM 600 | Malaysia |
| PB 311 | RRIM 600 × PB 235 | Malaysia |
| RRIC 52 | Primary clone | Sri Lanka |
| RRIC 100 | RRIC 52 × PB 83 | Sri Lanka |
| RRIC 102 | RRIC 52 × RRIC 7 | Sri Lanka |
| RRIC 105 | RRIC 52 × Tjir 1 | Sri Lanka |

region. Three primary clones (ortet selections) and twelve secondary clones (clones derived from known parentage) evolved in India, Indonesia, Malaysia and Sri Lanka were included in the study. The clones and their basic details are given in Table 1. The design adopted was a randomized complete block design with three replications. The experimental plots consisted of 36 plants in a square planting at spacings of 4 × 4 m giving a plant density of 638 plants $ha^{-1}$. The plots had a common border row of plants belonging to clone RRII 118.

*Field planting and crop management*

Field planting of the trial was carried out during July/August 1985. Two whorled plants raised in polythene bags (55 × 25 cm layflat dimension) for five months were used for planting. Standard cultural practices like manuring, life-saving irrigation during summer months, weeding, mulching and sun-scorch prevention were all part of the agronomic management of the crop. After the 1991–92 dry season, life-saving irrigation was discontinued. More details on these aspects can be found in Nazeer *et al.* (1992).

*Environmental measurements*

Weather characteristics at the location of the trial for the study period were collected from the meteorological observatory located near the trial area. Soil moisture levels in different months at depths of 0–30, 30–60 and 60–90 cm were determined by a gravimetric method with three replications for each depth during 1991–92. That year was chosen because life-saving irrigation was discontinued at this stage and hence the year would represent the prevailing soil moisture levels of the drier months in the area.

*Plant measurements*

Data on the girth collected at monthly intervals, starting from May 1989, over a period of six years were used in the present analysis. The girth of all trees at a height of 150 cm from the bud union was recorded for this purpose. Girth values for all three replications were used to determine monthly averages and monthly girth increments (GIN). To compare growth differences among the clones in different seasons, the year from June to May was divided into three seasons based on rainfall pattern and moisture availability. The wet season from June to September was the Monsoon season with excess soil moisture, the mid season from October to January was mostly rainless with good residual soil moisture and the dry season from February to May had rainless summer months with very low soil moisture levels. In order to match the growth of clones with the different seasons, the seasonal growth of each clone was obtained by subtracting the girth value in September from that in the preceding May, the January value from that in September and the May value from that in January to represent the wet, mid and dry seasons respectively.

Absolute girth (cm), seasonal girth increment (GIN, cm season$^{-1}$), seasonal mean girth increment (MGIN, cm season$^{-1}$) and annual MGIN (cm a$^{-1}$), were studied. Growth rates of the clones in terms of relative increment rate (RIR) per unit plant girth was also studied following Pearce (1976). Two parameters of growth rate, namely, seasonal mean relative increment rate (MRIR, mm cm$^{-1}$ season$^{-1}$) and annual MRIR (mm cm$^{-1}$ a$^{-1}$) were determined.

*Statistical analyses*

The data were subjected to analysis of variance for overall comparison and single degree of freedom analysis for identifying homogeneous groups. During February 1989 two plots belonging to clones RRII 6 and RRIC 102 in the third replication were destroyed by fire. Therefore the values for these plots were estimated by the missing plot technique (Steel and Torrie, 1960). To understand the effects of seasonal growth on the final growth, actual as well as percentage share of the seasonal mean girth increments and relative increment rates were correlated with final growth.

## RESULTS

*Environmental conditions*

The region received an annual rainfall of >2000 mm during the study period (Table 2) and the rainy period was from mid-June to mid-September. The remaining months rarely received any rain. The soil moisture status (Table 2) was very good from June to November and marginal from December to February. The summer months exhibited severe soil moisture stress conditions. Towards the end of the summer season, the soil moisture reached a level below the permanent wilting point. The sunshine hours (Table 3) during July and August were low, moderate in June and September and more than eight hours daily in the remaining months. Daily minimum temperatures (Table 3) were low in December, January and February and in the remaining months they were fairly high. Daily maximum temperatures (Table 3) exceeded 35 °C during March to May

Table 2. Monthly rainfall and soil moisture at the experimental area, North Konkan.

| | Rainfall (mm) | | | | | | Soil moisture 1991–92 (%)† | | |
|---|---|---|---|---|---|---|---|---|---|
| | Year | | | | | | Soil depth (cm) | | |
| Season and month | 1989–90 | 1990–91 | 1991–92 | 1992–93 | 1993–94 | 1994–95 | 0–30 | 30–60 | 60–90 |
| Wet | | | | | | | | | |
| June | 287 | 284 | 225 | 405 | 818 | 1264 | 34 | 36 | 32 |
| July | 823 | 495 | 1362 | 518 | 1068 | 1283 | S‡ | S | S |
| August | 613 | 649 | 425 | 994 | 289 | 950 | S | S | S |
| September | 228 | 481 | 77 | 533 | 694 | 291 | S | S | S |
| Mid | | | | | | | | | |
| October | 69 | 42 | 0 | 10 | 78 | 7 | 32 | 35 | 39 |
| November | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 37 | 39 |
| December | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 34 | 37 |
| January | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 30 | 32 |
| Dry | | | | | | | | | |
| February | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 25 | 26 |
| March | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 23 | 25 |
| April | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 22 | 23 |
| May | 107 | 0 | 0 | 0 | 0 | 0 | 15 | 21 | 22 |
| Total | 2127 | 1951 | 2089 | 2460 | 2947 | 3795 | — | — | — |

†Field capacity = 30.5%; permanent wilting point = 17.5%; bulk density = $1.3 \times 10^3$ kg;
‡S = saturated.

Table 3. Mean monthly sunshine duration (SSD, hours and minutes), minimum temperature (Tmin, °C), maximum temperature (Tmax, °C) and evaporation (mm) during the study period (1986–93) in North Konkan.

| Weather variable | Month | | | | | | | | | | | | Annual mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug | Sep | Oct. | Nov. | Dec. | |
| SSD | | | | | | | | | | | | | |
| Mean | 10.0 | 10.2 | 10.2 | 10.6 | 9.5 | 4.4 | 2.1 | 1.6 | 4.5 | 8.5 | 9.3 | 9.3 | 7.3 |
| Minimum | 6.0 | 3.5 | 6.3 | 7.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 1.0 | 0.2 | 2.0 |
| Maximum | 10.5 | 11.1 | 11.1 | 12.0 | 12.0 | 12.0 | 11.1 | 9.4 | 10.5 | 11.0 | 10.5 | 10.4 | 12.0 |
| Tmin | | | | | | | | | | | | | |
| Mean | 13.9 | 15.2 | 18.1 | 21.9 | 25.4 | 25.4 | 24.4 | 23.8 | 23.4 | 21.1 | 17.7 | 14.6 | 20.4 |
| Minimum | 6.5 | 9.5 | 13.0 | 14.0 | 22.0 | 22.0 | 22.0 | 22.0 | 21.0 | 15.5 | 12.0 | 7.5 | 6.5 |
| Maximum | 18.5 | 21.0 | 24.5 | 27.5 | 28.5 | 29.5 | 28.0 | 28.0 | 27.0 | 28.5 | 26.0 | 23.0 | 29.5 |
| Tmax | | | | | | | | | | | | | |
| Mean | 31.7 | 32.2 | 34.9 | 36.7 | 36.3 | 33.0 | 29.4 | 28.7 | 30.4 | 33.7 | 33.3 | 31.5 | 32.6 |
| Minimum | 22.5 | 27.0 | 27.0 | 31.0 | 31.0 | 24.0 | 24.5 | 25.0 | 24.0 | 26.5 | 28.0 | 25.0 | 22.5 |
| Maximum | 36.5 | 38.0 | 41.0 | 43.5 | 42.5 | 39.5 | 33.5 | 31.5 | 37.0 | 37.5 | 37.0 | 34.5 | 43.5 |
| Evaporation | | | | | | | | | | | | | |
| Mean | 4.6 | 5.7 | 6.7 | 7.9 | 7.6 | 5.3 | 3.0 | 2.4 | 3.3 | 4.6 | 4.6 | 4.2 | 5.0 |
| Minimum | 1.6 | 2.5 | 2.0 | 4.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 2.0 | 0.6 | 0.0 |
| Maximum | 7.0 | 8.4 | 12.3 | 14.3 | 14.0 | 12.0 | 6.2 | 6.1 | 7.2 | 8.0 | 9.0 | 8.0 | 14.3 |

and in the other months they were below 35 °C. During November the daily maximum temperature fluctuated less and on most days it was below 35 °C. In February it fluctuated between 26 and 37 °C. During April the maximum temperature was more than 36 °C on most days and on some days it reached 41 °C. Evaporation (Table 3) was low in July, August and September, moderate in June and from October to February and high during the summer months.

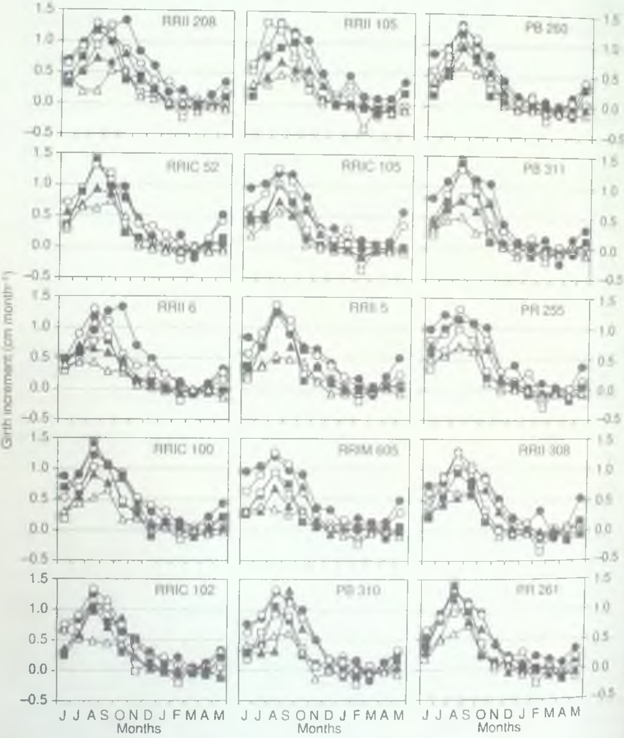


Fig. 1. Monthly variations in girth increments for clones of rubber during the immaturity period in 1989–90 (●), 1990–91 (○), 1991–92 (■), 1992–93 (□), 1993–94 (▲) and 1994–95 (△).

*Growth analysis and overall performance*

All the clones showed a similar pattern of growth (Fig. 1). In general maximum growth was observed in August. Girth growth started declining from September and in November it was minimal. The growth from December onwards was negligible. In the summer months a significant number of trees representing most of the clones showed a reduction in girth ranging from 0.2 to 0.5 cm.

There was considerable variation but a progressive decline in growth with age (Table 4; Fig. 2). Maximum growth occurred in the wet season. In the mid season

Table 4. Mean, minimum and maximum seasonal mean girth increments (MGIN, cm season$^{-1}$), mean relative increment rates (MRIR, mm cm$^{-1}$ season$^{-1}$) and coefficients of variation (c.v.) for rubber clones during a six-year study period (1986–93) in North Konkan.

| | Year of study | | | | | |
|---|---|---|---|---|---|---|
| Parameter | 1 | 2 | 3 | 4 | 5 | 6 |
| *Wet season* | | | | | | |
| MGIN | | | | | | |
| Mean | 3.9 | 4.1 | 3.1 | 3.0 | 2.4 | 1.9 |
| Minimum | 2.3 | 3.2 | 1.8 | 1.9 | 1.2 | 0.8 |
| Maximum | 5.4 | 5.3 | 5.3 | 6.2 | 3.3 | 3.3 |
| c.v. | 15.0 | 11.5 | 26.5 | 24.2 | 20.5 | 30.2 |
| MRIR | | | | | | |
| Mean | 2.0 | 1.5 | 1.0 | 0.8 | 0.6 | 0.5 |
| Minimum | 1.2 | 1.0 | 0.5 | 0.6 | 0.3 | 0.2 |
| Maximum | 2.6 | 2.2 | 2.0 | 1.9 | 1.0 | 0.9 |
| c.v. | 15.0 | 17.2 | 32.7 | 27.9 | 27.1 | 34.9 |
| *Mid season* | | | | | | |
| MGIN | | | | | | |
| Mean | 1.8 | 1.5 | 0.4 | 0.6 | 1.0 | 0.3 |
| Minimum | 0.3 | 0.5 | −0.3 | −0.2 | 0.2 | −0.4 |
| Maximum | 3.1 | 2.8 | 1.3 | 1.1 | 1.6 | 1.2 |
| c.v. | 41.4 | 32.0 | 81.8 | 45.0 | 29.8 | 94.5 |
| MRIR | | | | | | |
| Mean | 0.8 | 0.5 | 0.1 | 0.1 | 0.2 | 0.1 |
| Minimum | 0.1 | 0.2 | −0.1 | −0.1 | 0.1 | −0.1 |
| Maximum | 1.3 | 0.9 | 0.4 | 0.3 | 0.4 | 0.2 |
| c.v. | 36.1 | 30.4 | 83.2 | 41.4 | 28.6 | 94.0 |
| *Dry season* | | | | | | |
| MGIN | | | | | | |
| Mean | 0.7 | 0.2 | −0.1 | −0.2 | −0.2 | −0.2 |
| Minimum | −0.1 | −0.5 | −0.4 | −0.6 | −0.5 | −0.5 |
| Maximum | 1.6 | 0.9 | 0.5 | 0.0 | 0.0 | 0.0 |
| c.v. | 55.1 | 154.0 | −306.3 | −52.1 | −68.7 | −56.9 |
| MRIR | | | | | | |
| Mean | 0.3 | 0.1 | 0.0 | −0.1 | 0.0 | −0.1 |
| Minimum | 0.0 | −0.2 | −0.1 | −0.2 | −0.1 | −0.1 |
| Maximum | 0.6 | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 |
| c.v. | 56.8 | 172.7 | −365.8 | −52.1 | −69.6 | −59.3 |

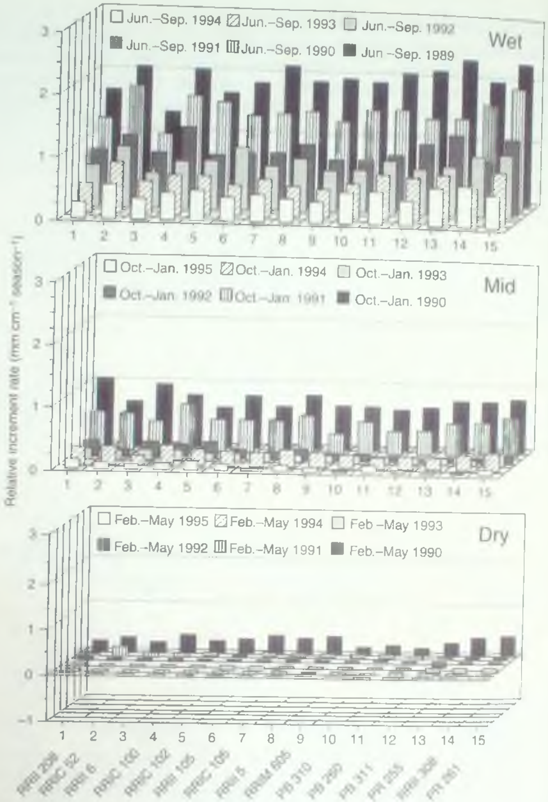


Fig. 2. Clonal variations in relative increment rates for the girth of rubber during the wet, mid and dry seasons in different years.

growth was reduced by more than 60% compared with the wet season and in the dry season growth rates were reduced severely. Seasonal and annual growth differences among the clones varied (Table 5). At the start of the study period the largest girth was for clone RRII 6 followed by RRII 208. PR 261 with a girth of only 14.26 cm was the least vigorous of the clones. During the wet season, the

Table 5. Clonal variations in absolute girth of rubber (cm) in May 1989 and 1995, seasonal mean girth increments (MGIN, cm season$^{-1}$), seasonal mean relative increment rates (MRIR, mm cm$^{-1}$ season$^{-1}$), annual MGIN (cm a$^{-1}$) and annual MRIR (mm cm$^{-1}$ a$^{-1}$) in experiments in North Konkan.

| Rubber clones | [illegible] May 1989 | Wet season | | Mid season | | Dry season | | [illegible] | | [illegible] May 1995 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MGIN | MRIR | MGIN | MRIR | MGIN | MRIR | MGIN | MRIR | |
| RRII 208 | 22.1 | 3.0 | 0.91 | 1.49 | 0.43 | 0.02 | 0.02 | 4.6 | 1.4 | 49.3 |
| RRIC 52 | 17.2 | 3.6 | 1.23 | 0.99 | 0.33 | 0.10 | 0.06 | 4.7 | 1.6 | 45.3 |
| RRII 6 | 22.5 | 2.6 | 0.81 | 1.11 | 0.35 | 0.05 | 0.01 | 3.7 | 1.2 | 44.9 |
| RRIC 100 | 17.0 | 3.3 | 1.16 | 1.19 | 0.40 | 0.07 | 0.05 | 4.6 | 1.6 | 44.3 |
| RRIC 102 | 19.3 | 3.1 | 1.03 | 1.02 | 0.32 | 0.04 | 0.03 | 4.1 | 1.4 | 44.0 |
| RRII 105 | 19.3 | 3.0 | 1.02 | 0.97 | 0.31 | −0.03 | 0.01 | 4.0 | 1.4 | 43.1 |
| RRIC 105 | 19.0 | 3.1 | 1.06 | 0.77 | 0.25 | 0.07 | 0.04 | 3.9 | 1.4 | 42.5 |
| RRII 5 | 17.8 | 2.9 | 1.05 | 1.04 | 0.35 | 0.08 | 0.05 | 4.0 | 1.4 | 42.0 |
| RRIM 605 | 19.8 | 2.4 | 0.95 | 0.75 | 0.24 | 0.12 | 0.05 | 3.6 | 1.2 | 41.4 |
| PB 310 | 18.9 | 2.8 | 1.01 | 0.84 | 0.28 | −0.04 | 0.00 | 3.7 | 1.3 | 40.9 |
| PB 260 | 18.0 | 3.1 | 1.11 | 0.69 | 0.23 | −0.02 | 0.01 | 3.8 | 1.3 | 40.7 |
| PB 311 | 18.6 | 3.1 | 1.10 | 0.72 | 0.24 | −0.12 | −0.02 | 3.7 | 1.3 | 40.5 |
| PR 255 | 16.7 | 3.2 | 1.21 | 0.79 | 0.28 | −0.11 | −0.02 | 3.9 | 1.5 | 40.2 |
| RRII 308 | 17.0 | 3.1 | 1.12 | 0.79 | 0.29 | 0.00 | 0.03 | 3.9 | 1.4 | 40.1 |
| PR 261 | 14.3 | 3.2 | 1.30 | 0.93 | 0.36 | 0.01 | 0.03 | 4.2 | 1.7 | 39.3 |
| [illegible] | 1.5 | 0.1 | 0.07 | [illegible] | [illegible] | 0.05 | 0.02 | [illegible] | 0.1 | [illegible] |

highest MGIN was for clone RRIC 52 and the lowest was for clone RRII 6. In the same season, PR 261 had the highest MRIR and RRII 6 the lowest. In the mid season RRII 208 exhibited the highest MGIN and PB 260 the lowest. Clone RRII 208 showed the highest MRIR, clone PB 260 the lowest. In the dry season most of the clones showed negligible growth. On an annual basis the highest MGIN was for clone RRIC 52, the lowest for RRIM 605. The highest MRIR was for clone PR 261, the lowest for RRII 6. At the end of the study period the maximum growth observed was for clone RRII 208 and the lowest for PR 261. The clones formed two homogeneous groups. Clones RRII 208, RRIC 52, RRII 6, RRIC 100, RRIC 102 formed the high growth group and RRII 105, RRIC 105, RRII 5. RRIM 605, PB 310, PB 260, PB 311, PR 255, RRII 308 and PR 261 formed the low growth group. The proportion of trees attaining tappable girth (Table 6) was greatest (52.4%) for clone RRII 208 and lowest (2.7%) for PR 261. The general trend was similar to that of girth and the pooled average for the proportion of trees attaining tappable girth was only 17.5%.

Of the total growth in a year 76.1% occurred in the wet season, 23.4% in the mid season and 0.5% in the dry season (Fig. 3). The correlation between wet season MGIN and final growth (Table 7) was negligible but those of percentage MGIN and percentage MRIR with final growth were negative and significant. For the mid-season growth values all correlations were positive and highly significant. Correlations obtained for dry season growth were not significant, the sign and magnitude of the coefficients being consistent with the correlations obtained for the mid season.

Table 6. Proportion of rubber trees attaining tappable girth after nine years of growth in North Konkan.

| Clone | Total number of trees | Trees attaining tappable girth (Number) | (%) |
|---|---|---|---|
| RRII 208 | 103 | 54 | 52.4 |
| RRIC 52 | 90 | 22 | 24.4 |
| RRII 6 | 68 | 24 | 35.3 |
| RRIC 100 | 98 | 21 | 21.4 |
| RRIC 102 | 64 | 21 | 32.8 |
| RRII 105 | 85 | 13 | 15.3 |
| RRIC 105 | 92 | 15 | 16.3 |
| RRII 5 | 92 | 8 | 8.7 |
| RRIM 605 | 82 | 15 | 18.3 |
| PB 310 | 93 | 7 | 7.5 |
| PB 260 | 88 | 8 | 9.1 |
| PB 311 | 73 | 4 | 5.5 |
| PR 255 | 78 | 4 | 5.1 |
| RRII 308 | 87 | 3 | 3.5 |
| PR 261 | 73 | 2 | 2.7 |
| Overall | 1266 | 221 | 17.5 |


Fig. 3. Generalized seasonal growth pattern for *Hevea* grown in North Konkan under rainfed conditio

Table 7. Correlation coefficients of seasonal mean girth increment (MGIN) and mean relative increment rate (MRIR) (actual and percentage share) with growth performance for clones of rubber grown in North Konkan.

| Season | MGIN Actual (cm season$^{-1}$) | MGIN Percentage share | MRIR Actual (mm cm$^{-1}$ season$^{-1}$) | MRIR Percentage share |
|---|---|---|---|---|
| Wet | 0.031 | −0.799** | −0.479 | −0.796** |
| Mid | 0.860** | 0.787** | 0.663** | 0.778** |
| Dry | 0.405 | 0.378 | 0.302 | 0.301 |

**Significant at $p < 0.01$.

## DISCUSSION

In North Konkan, though the annual rainfall is rather high, its distribution is far from satisfactory. The entire rainfall is received in the period from mid-June to mid-September, which results in long dry periods extending from November to May. December to February is the winter and the summer period is from March to May, during which the drought conditions become very severe. In these months high atmospheric heat load and vapour pressure deficits with soil moisture conditions near the permanent wilting point create adverse conditions for the growth of *Hevea*. Thus the environment is mainly water-limiting.

The small amount of growth observed for the clones in June may not be real but due mainly to the complete restoration of turgor which was lost during the severe stress conditions which preceded. In the following month appreciable increases in girth observed for all clones indicated that there had been no severe damage to the photosynthetic machinery in the preceding stress periods. Maximum growth of all clones in August was probably due to the compound interest effect of the previous growth.

As the plants grew the rate of growth declined progressively in all seasons. This trend was in agreement with the reported literature for a variety of crops as well as for rubber (Templeton, 1968; Chandrashekar *et al.*, 1994). An interesting observation noted in the wet season was the presence of a low growth rate in clones with a large girth and vice versa. Similar observations have already been reported (Chandrashekar *et al.*, 1994). During the mid season the trend was reversed in clones with a large girth which exhibited a high growth rate and those with a small girth exhibiting low growth rate. Gradual increases in mid-season growth in most of the clones during 1991–92 to 1993–94 appeared to be associated with the quantity of rainfall received in the respective mid seasons. In the dry seasons the growth rates of all clones reduced drastically. The small amount of growth observed in the clones during the 1990 dry seasons might be due to the effect of early showers received during May. From the third year of study the growth observed in the summer months was negligible and in most of the plants a reduction in girth was also noticed. The reduction was up to 90% of that of the wet season and up to 75% of that of the mid season. From the third year onwards there was a reduction in girth in most of the clones, caused by the severe stress conditions.

It is well known that temperature and water availability are the two most important constraints for growth and yield of plants throughout the world. When the ambient temperatures are above optimum, the substrates that could go into growth are increasingly lost through excessive respiration (Hellmers and Warrington, 1982). In the present study the observed shrinkage of tree stems (reduction in girth) in the dry season could be due to the continuous depletion of soil moisture accompanied by adverse atmospheric conditions. This type of stem shrinkage resulting from drought has been confirmed in many temperate and tropical species of angiosperms and gymnosperms (Kozlowski, 1972). Comparable findings have also been observed in another nine clones of rubber in a different experiment laid out at the same location (Chandrashekar, 1993 unpublished). In the initial two years of the study period a reduction in girth was either negligible or nil but was more pronounced in the subsequent years. Therefore, it can be presumed that increased leaf area might also have contributed to the reduction in girth during the summer months.

During the monsoon period, even though many days were cloudy with low sunshine hours, girth increase was good indicating that the plants had received adequate photosynthetically active radiation. Further, from the results of an irrigation experiment conducted at the same location, it has been reported that in spite of full potential irrigation during the dry period, maximum growth obtained was less than fifty per cent of the growth observed in the preceding monsoon period (Mohankrishna *et al.*, 1991). Therefore, prima facie it appears that *Hevea* prefers conditions of low vapour pressure deficits for good growth.

Although there were no apparent limiting factors from September to November, the growth of *Hevea* plants started to decrease and, from November onwards, very little growth was observed. This was not explainable and needs to be investigated further. It also poses a question as to whether the growth in *Hevea* follows a rhythm? The data indicated that in North Konkan, the active growth period for *Hevea* was about three months from July to September. It is known that the annual growth period determines the length of the pre-production years and in *Hevea* girth growth is the most important parameter for evaluating the maturity of the plantation in relation to harvesting the latex which is of commercial importance (Sethuraj and George, 1980; Paardekooper, 1989). Generally, within a clone the yield is positively correlated with the girth. The length of the immaturity period is also important because it determines how long farmers will have to wait for generating income from their plantations. Ideally the plantation is considered mature (that is tappable) if 50–70% of the trees have attained a girth of 50 cm at a height of 1.25 m (Sethuraj and George, 1980; Paardekooper, 1989). In the present study after nine years of growth, only clone RRII 208 could satisfy this condition. In all other clones the percentage of trees attaining a suitable girth was well below 50%. Therefore it was obvious that the conditions prevailing in

Konkan would prolong the immaturity period in *Hevea* in that region and, under rainfed cultivation, it would not be less than nine years before the latex could be harvested. In tropical humid climates the immaturity period under rainfed conditions will not be more than 6–7 years (Webster, 1989). From the analysis based on final growth performance, it can be concluded that clones RRII 208, RRIC 52, RRII 6, RRIC 100, RRIC 102 are tolerant of drought whereas RRII 105, RRIC 105, RRII 5, RRIM 605, PB 310, PB 260, PB 311, PR 255, RRII 308 and PR 261 are less tolerant of drought.

From the generalized growth pattern it is clear that most of the growth occurred in the wet and mid seasons and the contribution to growth in the dry period was negligible. Chandrashekar *et al.* (1994; 1996) have already reported similar results. Correlations obtained for seasonal growth and growth rates with final growth performance are very interesting. Significant correlations obtained for mid-season growth with growth performance indicated that the best girth growth found in the leading clones was due to substantial growth occurring during the mid seasons. Therefore it can be concluded that clones which show more growth during mid seasons are likely to have better overall growth performance in drought environments. These clones generally exhibited a slightly slower growth rate during the wet seasons indirectly indicating that these clones may be physiologically better adapted to dry conditions. The results show that by analysing the growth of rubber, potentially drought tolerant clones can be identified.

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