*Rubber Science*, **26**(2): 250-258, 2013

# GROWTH AND EARLY YIELD POTENTIAL OF A FEW RRII 300 SERIES, IRCA AND OTHER CLONES OF *HEVEA BRASILIENSIS* UNDER THE DRY SUB-HUMID CLIMATE OF ODISHA, EASTERN INDIA

**Bal Krishan**

Regional Research Station, Rubber Research Institute of India, Rubber Board
Dhenkanal-759 001, Odisha, India

*Received:* 10 January 2013 *Accepted:* 02 July 2013

Krishan, B. (2013). Growth and early yield potential of a few RRII 300 series, IRCA and other clones of *Hevea brasiliensis* under the dry sub-humid climate of Odisha, eastern India. *Rubber Science*, **26**(2): 250-258.

The growth, girth increment, early dry rubber yield and timber yield of RRII 300 series, IRCA and a few other promising clones in the dry sub humid climate of Odisha in eastern region of India is reported. Prolonged high temperature, low rainfall and soil moisture are the major environmental constrains affecting the growth, yield and adaptability of clones in the region. Clone RRII 351 recorded the initial highest mean rubber yield (31.03 g $t^{-1}t^{-1}$) followed by IRCA 109 (30.69 g $t^{-1}t^{-1}$ ), whereas popular clones RRIM 600 and RRII 105 recorded 26.59 and 26.75 g $t^{-1}t^{-1}$, respectively. Highest and lowest yield was recorded during winter and summer months, respectively. RRII 300 attained highest girth (53.03 cm) and girth increment but yield was relatively low. Highest bark thickness was recorded in PB 28/59 (6.97 mm) followed by 6.75 mm in RRII 357 and RRII 51. Highest bole volume was recorded in RRII 300 (0.07 $m^3$ $tree^{-1}$) followed by IRCA 111 (0.06 $m^3$ $tree^{-1}$). IRCA 111 recorded medium yield of 26.03 g $t^{-1}t^{-1}$, on par with that of the popular clones. In general, the clones RRII 351, RRII 352 and IRCA 109 were found to be more promising than the popular clones RRII 105 and RRIM 600 for early yield. The results of the present study will aid in the identification of potential clones for possible commercial cultivation in the region.

**Keywords:** Clone performance, Dry sub-humid climate, Girth, Timber, Yield

## INTRODUCTION

The Para rubber tree, *Hevea brasiliensis* (Willd.ex Adr.de Juss.) Muell. Arg. is a tropical tree native to Amazon rainforest. More than 90 per cent of the world natural rubber (NR) is obtained from rubber tree latex (Verheye, 2010). Rubber has been traditionally cultivated in the equatorial region, in a zone lying between 10° north and 10° south of equator.

Compared to other crops, rubber is a relatively new introduction, having been brought in to cultivation in India a century ago. In the country the traditional rubber belt (8-12° N) encompasses the southern tips of the peninsula, where it provide appropriate environmental conditions and has been grown on a plantation scale for nearly a century.

The shrinking availability of cultivable land in the traditional region and ever

Correspondence: B. Krishan (Email: balakrishan@rubberboard.org.in)

growing demand for NR has supported the extension of rubber cultivation to areas of diverse agro-climatic zones of the country (Sethuraj *et al.*, 1991). Odisha state (17-22° N) in eastern region of India was consequently identified as one of the potential non-traditional area where NR plantation can thrive well. Such plantations are being established in environments grossly different from those to which the species is best adapted. It has also been observed that clone which performs well in one environment may not perform as well in other environment.

In this region of Odisha state, few abiotic factors as high temperature with severe scorching summer, low and erratic rainfall and low soil moisture are important constrains affecting the growth and yield potential of the rubber crop. Limited reports are available on the performance of few rubber clones in the Odisha region (Meenatoor *et al.*, 2000; Gupta *et al.*, 2001; 2002). However, no information on performance of RRII 300 series and IRCA clones in this region is available so far.

The present paper summarizes data on growth, early yield, timber value and adaptability of eleven clones in the dry sub-humid climate of Odisha in the eastern region of India.

## MATERIALS AND METHODS

The clone evaluation trial with eleven *Hevea* clones was initiated during 1999 at the Rubber Board, Regional Research Station at Kadalipal, Dhenkanal, Odisha (20° 49′ N; 85° 30′ E; 100 m MSL). The soil of the area is acidic and classified as loamy sand in texture and is of lateritic in nature.

The genetic materials used in the trial are comprised of four RRII 300 series (RRII 300, RRII 351, RRII 352, RRII 357), two IRCA clones (IRCA 109, IRCA 111) and five other potential clones (RRII 208, RRII 105, RRII 51, PB 28/59, RRIM 600). The experimental design was randomized complete block with four replications and thirty six plants per plot planted at a spacing of 4.6 m x 4.6 m. Brown budded stumps were used as planting material. The plants were raised following the cultural practices recommended for the rubber growing region (Rubber Board, 1990). In the initial years, partial life saving irrigation of 20 L per week was provided in summer months.

The trunk girth was recorded at regular quarterly intervals at 150 cm above the ground level. The first three years measurement was taken as diameter, since the plants were too small to measure girth. Plant diameter was measured 15 cm above the bud union with a slide caliper and converted to girth, assuming that the stem was cylindrical. Annual girth increment was calculated for three different phases each comprising of four years duration, during the entire period of 12 years after planting.

The trees were opened for tapping at the 12$^{th}$ year after planting. The tapping system followed was 1/2S d/2 6d/7. Dry rubber yield was recorded fortnightly intervals following cup coagulation method. The yield data over early two years were used for evaluation of clones. In order to assess the seasonal performance, a year has been grouped in to three seasons, as rainy (June to September), winter (October to January) and summer (February to May). The per cent depression in yield in summer months during the period was worked out. The projected commercial yield was determined for 350 trees per hectare per year, for 120 tapping days in a year.

The primary branch number and trunk height up to the main fork of entire

Table 1. **Weather parameters during the study period**

| Month | Temperature (°C) | | Rainfall | Rainy | Sunshine | Evaporation |
|---|---|---|---|---|---|---|
| | Tmax | Tmin | (mm) | days | (hrs) | (mm) |
| January | 28.2 | 12.9 | 12.2 | 1 | 7.3 | 2.8 |
| February | 32.0 | 16.9 | 7.3 | 1 | 8.0 | 3.6 |
| March | 35.7 | 20.6 | 12.4 | 1 | 8.1 | 4.7 |
| April | 39.8 | 24.1 | 39.1 | 3 | 8.6 | 6.3 |
| May | 39.6 | 24.9 | 83.7 | 5 | 8.1 | 6.2 |
| June | 35.9 | 25.4 | 182.9 | 11 | 5.3 | 4.3 |
| July | 32.5 | 24.7 | 350.1 | 19 | 3.9 | 2.4 |
| August | 32.3 | 24.7 | 278.4 | 16 | 4.1 | 2.3 |
| September | 32.3 | 24.1 | 191.0 | 11 | 4.8 | 2.2 |
| October | 32.1 | 22.3 | 133.1 | 6 | 7.1 | 2.7 |
| November | 30.0 | 16.2 | 9.9 | 1 | 7.1 | 2.7 |
| December | 28.4 | 13.2 | 4.3 | 1 | 7.2 | 2.7 |
| Total/Mean | 33.2 | 20.8 | 1304.4 | 76 | 6.6 | 3.6 |

trees were measured, and clear bole volume per tree was estimated in the 12[th] year after planting following the quarter girth method (Chathurvedi and Khanna, 1982). The bark thickness of 16 trees of each clone at the time of opening of the panel for tapping was recorded. The data were statistically analyzed according to the standard procedure (Sukhatme and Amble, 1989).

## RESULTS AND DISCUSSION

The region represents dry sub-humid climate with stressful conditions. The region received an annual rainfall of 1304 mm during the study period and the rainy period was 76 days, mainly confined to mid June to September. The distribution of rainfall is far from satisfactory which results in long dry spells extending from November to May, during which the drought conditions become severe. The summer months (February to May) exhibited severe soil moisture stress conditions. The sunshine hours during July and August were low, moderate in June and September and more than seven hours daily in the remaining months. Daily minimum temperature was low in November, December and January and high in the remaining months. Daily

Table 2. **Mean annual yield of clones over two years under dry sub-humid conditions**

| Clone | Mean annual yield ($gt^{-1}t^{-1}$) | Projected yield ($Kgha^{-1}yr^{-1}$) |
|---|---|---|
| RRII 300 | 23.35 (9) | 882.6 |
| RRII 351 | 31.03 (1) | 1172.9 |
| RRII 352 | 28.40 (3) | 1073.5 |
| RRII 357 | 26.54 (6) | 1003.2 |
| IRCA 109 | 30.69 (2) | 1160.0 |
| IRCA 111 | 26.03 (7) | 983.9 |
| RRII 208 | 19.72 (11) | 745.4 |
| RRII 105 | 26.75 (4) | 1011.1 |
| RRII 51 | 21.25 (10) | 803.2 |
| PB 28/59 | 23.50 (8) | 888.3 |
| RRIM 600 | 26.59 (5) | 1005.1 |
| CD (P=0.05) | 4.35 | — |
| CV | 11.64 | — |

Figures in parenthesis depicts ranking of clones

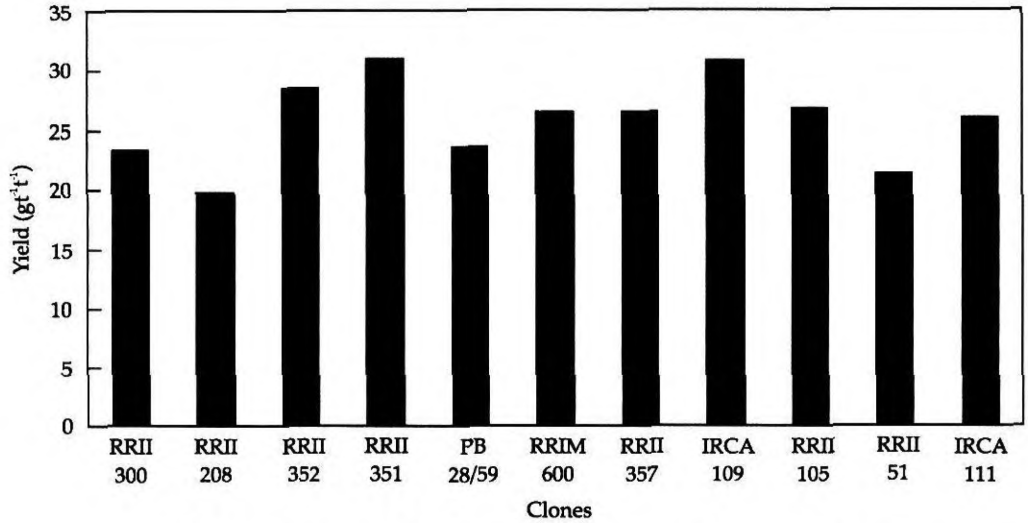


Fig. 1. Mean annual yield performance over two years of different clones

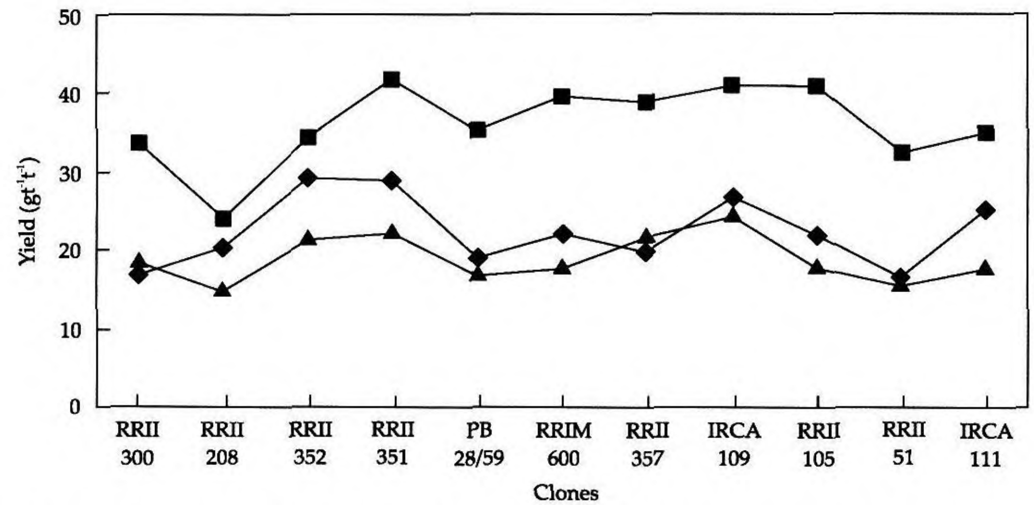


Fig. 2. Yield performance of clones in rainy (J-J-A-S), winter (O-N-D-J) and summer (F-M-A-M) seasons over initial two years

maximum temperature exceeds 35 °C during March, April, May and June. During the month of April and May, the mean maximum temperature recorded was 40 °C. Evaporation was low during July, August and September and high during summer months (Table 1).

Significant clonal variation in terms of initial annual mean yield of dry rubber over two years of tapping has been recorded. The

Table 3. **Monthly rubber yield of different clones over initial two years tapping**

| | Yield($gt^{-1}t^{-1}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clone | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May |
| RRII 300 | 14.55 | 20.96 | 14.28 | 19.74 | 28.60 | 38.43 | 39.80 | 29.74 | 24.43 | 19.78 | 17.03 | 12.88 |
| RRII 351 | 18.45 | 36.45 | 23.00 | 37.48 | 41.24 | 40.45 | 49.10 | 37.02 | 25.13 | 28.46 | 18.59 | 17.03 |
| RRII 352 | 16.30 | 36.35 | 30.68 | 34.99 | 30.61 | 37.54 | 33.95 | 33.83 | 23.90 | 21.28 | 22.23 | 19.13 |
| RRII 357 | 12.13 | 18.59 | 24.10 | 24.93 | 30.36 | 40.31 | 46.30 | 36.86 | 28.25 | 24.46 | 21.55 | 10.68 |
| IRCA 109 | 21.98 | 32.29 | 27.35 | 26.78 | 36.79 | 45.84 | 41.80 | 38.49 | 33.80 | 25.11 | 19.31 | 18.75 |
| IRCA 111 | 13.98 | 26.46 | 20.45 | 40.45 | 42.69 | 32.30 | 35.05 | 30.18 | 22.20 | 19.59 | 14.31 | 14.73 |
| RRII 208 | 17.16 | 21.04 | 21.95 | 22.71 | 22.10 | 24.04 | 24.98 | 23.11 | 17.11 | 17.23 | 13.50 | 11.73 |
| RRII 105 | 15.05 | 20.16 | 19.15 | 32.56 | 49.99 | 45.79 | 43.70 | 24.36 | 21.79 | 22.29 | 16.74 | 10.00 |
| RRII 51 | 11.83 | 20.05 | 13.83 | 19.56 | 30.79 | 38.59 | 31.60 | 26.74 | 16.78 | 18.20 | 13.99 | 13.10 |
| PB 28/59 | 13.80 | 23.75 | 15.65 | 22.46 | 28.54 | 40.70 | 43.13 | 26.36 | 15.14 | 14.14 | 19.34 | 18.95 |
| RRIM 600 | 13.85 | 24.56 | 19.58 | 31.84 | 34.53 | 41.11 | 43.00 | 39.49 | 27.18 | 18.39 | 13.55 | 12.00 |
| CD (P=0.05) | 3.37 | 7.48 | 5.77 | 9.67 | 9.00 | NS | 11.47 | 9.90 | 6.13 | 6.39 | NS | 3.10 |
| CV | 15.12 | 20.21 | 19.02 | 23.38 | 18.14 | 22.10 | 20.12 | 21.69 | 18.20 | 21.19 | 25.23 | 14.83 |

yield of popular clone RRIM 600 was 26.59 g $t^{-1}t^{-1}$, while yield of rest of the clones under evaluation ranged from 19.72 g $t^{-1}t^{-1}$ to 31.03 g $t^{-1}t^{-1}$. Clone RRII 351 recorded the highest early mean yield (31.03 g $t^{-1}t^{-1}$), followed by IRCA 109 (30.69 g $t^{-1}t^{-1}$) and RRII 352 (28.40 g $t^{-1}t^{-1}$ ); where as RRII 208 recorded the lowest yield (19.72 g $t^{-1}t^{-1}$ ) (Table 2, Fig. 1). RRII 351 and IRCA 109 with high early annual mean yield with high summer yield were found relatively better clones (Table 3 and 4, Fig. 2). The coefficient of variation (CV) with respect to monthly yield variable among the clones was low to moderate ranging 14.83 per cent to 23.38 per cent. The annual yield among the clones under evaluation also indicated a low CV of 11.64 per cent suggesting high stability (Table 2 and 3). No literature is available on performance of rubber yield on the RRII 300 series and IRCA clones in dry sub-humid conditions. However, superior yield performance of IRCA 109 and IRCA 111 was reported in the traditional region (Reghu *et al.*, 2008).

Rubber yield increased gradually with the onset of monsoon particularly in the month of August, peaked in subsequent period, sustained up to December and started slight decline thereafter. Overall rubber yield was comparatively low during the summer period (February to May) and high during the winter (October to January) (Table 3 and 4, Fig. 2). A similar trend in few rubber clones were also reported earlier in dry sub-humid conditions (Chandrashekar *et al.*, 1990; Gupta *et al.*, 2002). In general top yielding clones RRII 351 and IRCA 109 recorded high yield 22.30 and 24.24 $gt^{-1}t^{-1}$, respectively during the summer period. The other superior yielders during summer were RRII 352 and RRII 357 recording 21.64 and 21.24 $gt^{-1}t^{-1}$, respectively. Summer yield depression of clones ranged from 29.39 per cent in RRII 208 to 48.5 per cent in RRII 351. Popular clones RRIM 600 and RRII 105 also

Table 4. **Summer mean yield of the clones over two years of tapping**

| Clone | Mean yield ($gt^{-1}t^{-1}$) | Summer yield ($gt^{-1}t^{-1}$) | Summer yield depression (%) |
|---|---|---|---|
| RRII 300 | 23.35 | 18.53 | 32.99 |
| RRII 351 | 31.03 | 22.30 | 48.50 |
| RRII 352 | 28.40 | 21.64 | 41.92 |
| RRII 357 | 26.54 | 21.24 | 37.16 |
| IRCA 109 | 30.69 | 24.24 | 42.59 |
| IRCA 111 | 26.03 | 17.71 | 42.69 |
| RRII 208 | 19.72 | 14.89 | 29.39 |
| RRII 105 | 26.75 | 17.71 | 45.98 |
| RRII 51 | 21.25 | 15.52 | 32.73 |
| PB 28/59 | 23.50 | 16.89 | 36.71 |
| RRIM 600 | 26.59 | 17.78 | 44.21 |
| CD (P=0.05) | 4.35 | 2.19 | 7.73 |
| CV | 11.64 | 15.72 | 15.15 |

recorded high summer yield depression (Table 4). The lower yield during summer months could be attributed to the stress imposed on the rubber due to soil moisture stress and synchrony of various other physiological complexities due to defoliation, flowering and refoliation (Chua, 1970).

Vigor in terms of tree growth is an important factor since early good yield is only possible for a tree which grows vigorously when young (Simmonds, 1989). Growth during the initial years is crucial for *Hevea* especially with respect to attainment of tappable girth (Sethuraj and George, 1980; Paardekooper, 1989). RRII 300 (53.03 cm) recorded the highest girth followed by IRCA 111 (50.53 cm) and RRII 208 (49.40 cm) at the time of opening of the trees for tapping. Girth of all rest of the clones was comparable to that of RRIM 600 (Table 5). Although IRCA 109 recorded the lowest girth at opening 38.30 cm, the clone recorded high rubber yield (30.69 $gt^{-1}t^{-1}$) among the evaluated clones (Table 2 & 5). Similarly other high yielding clones like RRII 351 and RRII 352 also recorded relatively low girth. This is in agreement with the report that high yield need not necessarily be associated with high girth (Goncalves *et al.*, 2006).

Table 5. **Growth performance of rubber clones over twelve year of field planting**

| Clones | Annual Girth Increment (cm) | | | Girth at opening | Bark thickness |
|---|---|---|---|---|---|
| | Juvenile period | Immature period | Mature period | (cm) | (mm) |
| RRII 300 | 3.44 | 4.57 | 4.97 | 53.03 (1) | 6.41 |
| RRII 351 | 3.67 | 3.36 | 3.64 | 45.33 (8) | 6.41 |
| RRII 352 | 3.92 | 4.66 | 2.58 | 46.80 (6) | 5.38 |
| RRII 357 | 3.31 | 4.44 | 2.92 | 45.68 (7) | 6.75 |
| IRCA 109 | 2.41 | 4.31 | 2.85 | 38.30 (11) | 5.43 |
| IRCA 111 | 2.65 | 6.92 | 2.73 | 50.53 (2) | 5.83 |
| RRII 208 | 3.17 | 5.20 | 3.66 | 49.40 (3) | 5.96 |
| RRII 105 | 2.25 | 4.28 | 4.59 | 43.70 (9) | 5.25 |
| RRII 51 | 2.06 | 3.86 | 3.74 | 40.08 (10) | 6.75 |
| RRIM 600 | 3.38 | 4.80 | 3.58 | 48.55 (5) | 6.00 |
| PB 28/59 | 3.54 | 4.02 | 2.92 | 48.70 (4) | 6.97 |
| CD (P=0.05) | NS | 1.57 | NS | NS | 0.91 |
| CV | 34.51 | 23.58 | 37.96 | 17.61 | 10.25 |

Ranking of clones in parenthesis

Trunk annual girth measurement is widely used in *Hevea* cultivation as a parameter of growth particularly during the immaturity period. This parameters is also commonly used in assessing growth performance of new planting material (Shorrocks *et al.*, 1965). Higher girth increment was observed during the immature four years period (2003-07) as compared to the juvenile four years period (1999-03) and early mature four years period (2007-2011). Overall, RRII 300, RRII 208 and RRII 352 recorded high mean annual girth increment during the entire periods, but these clones did not yield high. RRII 51 showed lowest mean annual girth increment (Table 5). The present report was comparable with other clone performance reports in dry sub-humid conditions (Chandrashekar *et al.*, 1998; Meenatoor *et al.*, 2000; Gupta *et al.*, 2002; Krishan *et al.*, 2007). Good girthing is important in sustaining yield in high yielding clones and also reducing wind damage losses through trunk snap (Tan, 1987).

Table 6. **Timber volume associated characters of different rubber clones after twelve years of planting**

| Clone height | Branching of primary (m) | Number volume branches | Bole ($m^3$ tree$^{-1}$) |
|---|---|---|---|
| RRII 300 | 3.06 | 2.73 | 0.07 |
| RRII 351 | 2.95 | 2.25 | 0.04 |
| RRII 352 | 2.84 | 2.68 | 0.04 |
| RRII 357 | 2.94 | 2.73 | 0.05 |
| IRCA 109 | 2.46 | 2.30 | 0.03 |
| IRCA 111 | 3.26 | 2.21 | 0.06 |
| RRII 208 | 2.81 | 2.19 | 0.05 |
| RRII 105 | 2.45 | 2.21 | 0.04 |
| RRII 51 | 2.48 | 2.62 | 0.04 |
| RRIM 600 | 2.67 | 2.37 | 0.05 |
| PB 28/59 | 2.69 | 2.93 | 0.04 |
| CD (P=0.05) | 0.45 | NS | 0.02 |
| CV | 11.25 | 17.81 | 29.04 |

Bark thickness of *Hevea* clones at juvenile stage have been reported as a clonal characteristics (Licy and Premakumari, 1988). Significant clonal variation for bark thickness was observed at the time of opening for tapping. Bark thickness was observed the highest in PB 28/59 ( 6.97 mm) followed by 6.75 mm in PB 28/59 and RRII 357, RRII 51 respectively. The popular clone RRIM 600 attained a bark thickness of 6.00 mm (Table 5). Goncalves *et al.* (2006) reports that thick bark is important because it minimizes wounding incidence, which is known to effect yield productivity on latter panels.

Clear bole volume is an indicator of the timber yield of a clone since the clear bole contributes 60 per cent of the timber recovered from a rubber tree (Najib *et al.*, 1995). Clonal variation for clear bole volume and height at forking were significant. The clones, superior in terms of clear bole volume were RRII 300 (0.07 $m^3$ $t^{-1}$) followed by IRCA 111 (0.06 $m^3$ $t^{-1}$). The mean height at forking was the highest in IRCA 111 (3.26 m) followed by RRII 300 (3.06 m). Popular clone RRIM 600, recorded 0.05 $m^3$ $t^{-1}$ and 2.67 m, bole volume and first forking height respectively (Table 6). The primary branches contributes significant role in formation of canopy and a balanced canopy plays an important role in wind resistance besides timber contribution. The number of primary branches varied from lowest 2.21 in RRII 105 to highest 2.73 in RRII 300 (Table 6).

In the present study based on initial yield performance, RRII 351, RRII 352, IRCA 109 and IRCA 111 were found to be better than that of the popular clones RRII 105 and RRIM 600 in the dry sub-humid condition. The good performance of clones suggests possible improvement for the yield and growth through selection. It is also postulated that yield data from the early years of tapping could be useful in predicting yield in later years of the clones. However, the performance needs to be confirmed based on further observations on growth and yield so as to identify clones suitable for commercial cultivation.

## ACKNOWLEDGEMENT

The author acknowledges the efforts of all scientists and field staff associated with this research work.

## REFERENCES

Chandrashekar, T.R., Jana, M.K., Thomas, J., Vijayakumar, K.R. and Sethuraj, M.R. (1990). Seasonal changes in physiological characteristics and yield in newly opened trees of *Hevea brasiliensis* in North Konkan. *Indian Journal of Natural Rubber Research*, **3**(2): 88- 97.

Chandrashekar, T.R., Nazeer, M.A., Marattukalam, J.G., Prakash, G.P., Annamalainathan, K. and Thomas, J. (1998). An analysis of growth and drought tolerance in rubber during the immature phase in a dry sub-humid climate. *Experimental Agriculture*, **34**: 287-300.

Chathurvedi, A.N. and Khanna, L.S. (1982). *Forest Mensuration*. International Book Distributor, Dehradun. 30 p.

Chua, S.E. (1970). *The Physiology of foliar senescence and abscission in Hevea brasiliensis Muell. Arg.* Ph.D. Thesis, Singapore University.

Goncalves, P.de S., Silva, M. de A., Gouvea, L.R.L., Scaloppi, J.R.E. (2006). Genetic variability for girth growth and rubber yield characters in *Hevea brasiliensis*. *Scientia Agricola*, **62**: 246-254.

Gupta, C., Rao, K.N., Edathil, T.T. and Saraswathyamma, C.K. (2001). Early performance of elite clones and polyclonal seedlings of rubber (*Hevea brasiliensis*) in lateritic soils of Odisha. *National Seminar on Plant Resources Management for Sustainable Development*, 25-26 March 2001, Bhubaneswar, Odisha, India. Plant Science Research, Abstracts pp. 50-51.

Gupta, C., Rao, K.N. and Edathil, T.T. (2002). Seasonal performance of three elite *Hevea* rubber clones in a less favourably suited edaphic and climatic conditions of Orissa. *PLACROYSM XV*, 2002, Mysore, Karnataka, India, pp. 64-71.

Krishan, B., Rao, K.N. and Nazeer, M.A. (2007). Growth performance of *Hevea brasiliensis* in a dry sub-humid climate of Bastar region in central eastern India. *Natural Rubber Research*, **20**(1&2): 56-60.

Licy, J. and Premakumari, D. (1988). Association of characters in hand pollinated progenies of *Hevea brasiliensis* (Willd.ex. Adr. De Juss.) Muell. Arg. *Indian Journal of Natural Rubber Research*, **1**(1): 18-21.

Meenattoor, J.R., Sasikumar, B., Soman, T.A., Gupta, C., Methi, S., Meenakumari, T., Nair, R.B., Licy, J., Saraswathyamma, C.K. and Brahmam, M. (2000). Genotype x Environment interaction in *Hevea* in Diverse agr-climatic conditions in India – Preliminary growth results. *Proceedings of the International Planters Conference*. May 2000. Kuala Lumpur, Malaysia, pp. 183-195.

Najib, L.B.A., Ranli, B.O. and Yaacob, A.R.B.W. (1995). *Hevea* wood availability in Peninsula, Malaysia. *Planter Bulletin*, **224-225**: 73-83.

Paardeekooper, E.C. (1989). Exploitation of the rubber tree. In: *Rubber*. (Eds. C.C. Webster and W.J. Baulkwill). Longman scientific and Technical, New York, pp. 350-414.

Reghu, C.P., Madhavan, J., Rao, G.P., Abraham, S.T. and Varghese, Y.A. (2008). Clones of rubber (*Hevea brasiliensis*) introduced from Cote d'Ivoire: Growth and yield performance in India. *Journal of Plantation Crops*, **36**(3): 175-179.

Rubber Board (1990). *Rubber and its cultivation*. Rubber growers Companion. Kottayam. pp. 3-28.

Sethuraj, M.R. and George, M.J. (1980). Tapping. In: *Handbook of Natural rubber Production in India* (Ed. P.N. Radhakrishna Pillay). The Rubber Board, Kottayam, India, pp. 209-229.

Sethuraj, M.R., Potty, S.N., Vijayakumar, K.R., Krishnakumar, A.K., Rao, S.P., Thapliyal, A.P., Mohankrishna, T., Rao, G.G., George, M.J., Soman, T.A. and Meenattoor, J. R. (1991). Growth performance of *Hevea* in the non-traditional regions of India. *Proceedings of the Rubber Growers' Conference*, 1989, Malacca, Malaysia, pp. 212-227.

Shorrocks, V.M., Templeton, J.K. and Iyer, G.G. (1965). Mineral nutrition, growth and nutrient cycling of *Hevea brasiliensis*. 3. The relationship between girth and shoot dry weight. *Journal of the Rubber Research Institute of Malaya*, **19**: 85-92.

Simmonds, N.W. (1989). Rubber breeding. In : *Rubber* (Eds. C.C. Webster and W.J. Baulkwill). Longman Scientific and Technical, New York, pp. 85-124.

Sukhatme, P.V. and Amble, V.N. (1989). *Statistical Methods for Agricultural Workers*. ICAR, New Delhi.

Tan, H. (1987). Strategies in rubber tree breeding. In: *Improving Vegetatively Propagated Crops*. (Eds. A.J. Abbott, and R.K. Atkin). Academic Press, London, pp. 27-62.

Verheye, W. (2010). Growth and production of rubber. In: *Land use, Land cover and Soil sciences* (Ed. W. Verheye), Encyclopedia of life support systems (EOLSS), UNESCO-EOLSS Publishers, Oxford, UK.