INCREASING PRODUCTIVITY OF RUBBER (*HEVEA BRASILIENSIS*) THROUGH HIGH DENSITY PLANTING IN NORTH EAST INDIA

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A long term field trial was conducted under sub-humid climatic condition at Agartala to study the effect of planting density on growth and yield of *Hevea brasiliensis*, clone RRII 429. Performance under six planting densities *viz*. 408, 445, 489, 544, 613 and 699 trees ha^{-1} was evaluated. Growth of the plants was significantly influenced by different densities only after the sixth year. Growth and yield per tree decreased with increasing planting density. Plants at the lower density showed high girth increment in all the years and produced thick virgin bark. Higher density resulted in lower girth, bark thickness and higher crotch height. However, it was vice-versa in the case of yield per hectare due to increase in number of trees under tapping with increasing planting density. From the study it appeared that the highest seven year average yield could be obtained at the density of around 613 trees ha^{-1}. However, planting density of 544 trees ha^{-1} gave the highest Benefit-Cost Ratio (BCR) and Internal Rate of Return (IRR) indicating that it is the economically viable planting option for North-East India.

Keywords: Density, Growth, *Hevea*, North East India, Rubber plantation, Yield

INTRODUCTION

The continuing decline in the availability of cultivable land and rising land costs together with mounting demand of natural rubber, have given thrust to the concept of high density planting of Natural Rubber (*Hevea brasiliensis*). High density planting is one of the important methods to achieve high productivity per unit area. The growing space largely influences tree growth and yield of a stand as a whole. The influence of spacing depends on a number of factors like clone, site characteristics, climatic conditions, management *etc*. However, growth and yield were strongly influenced by planting density in rubber (Obouayeba *et al*., 2005; Roy *et al*., 2005; Dey and Pal 2006; Varghese *et al*., 2006; Dey and Datta, 2013; Philip *et al*., 2014). High plant population adversely affects plant growth, while suboptimal plant population results in high yield per plant but lower yield per unit area. High plant density leads to competitive shading within the canopy, thereby limiting interception of radiation. Increasing plant density enhances intra-plant competition, decreasing growth of single plant. It also affects the canopy architecture, leaf area, dry matter production and ultimately, the economic productivity of rubber. Optimum

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plant density allows crop to exploit resources optimally and produce high yield.

Rubber cultivation is being extended to suboptimal region of India to meet the increasing demand. The Northeastern states have high potential area for natural rubber cultivation. The crop has gained popularity due to acceptability by people of NE region. Out of the 1,88,565 ha rubber area in this region in 2019-20 (Rubber Board, 2020), more than 80 per cent is in the small holding sector with an average holding size of one hectare. Since loss of trees due to strong wind is prevalent here during summer months, maintaining higher stand in the later years is a challenge for the growers.

Apart from the potential manipulation of latex production with different exploitation and stimulation (Dey, 2020), the high land productivity of latex could be obtained through high yielding genotype with optimum planting density. Optimum plant population is a prerequisite for obtaining high yield of any plantation. The present study was aimed to identify the optimum plant density for recently recommended clone RRII 429 for North East India.

MATERIALS AND METHODS

Field investigations were undertaken at the experimental farm of the Rubber Research Institute of India, Regional Research Station, Agartala (91°15′E and 23°53′N, 30 m above MSL). Climate of this location is warm and annual mean rainfall of the last 14 years (experimental period) was 1943 mm. The mean annual temperature was 25.4°C, the mean maximum and minimum temperature were 30.8°C and 19.9°C respectively during the above period. The soil of the experimental site is clay loam in texture, low in carbon (0.97%), available phosphorous (2.8 mg 100 g^{-1}) and available potassium (5.2 mg 100 g^{-1}) with a pH of 4.6.

Recommended high yielding clone RRII 429 was planted in six densities during 2007 in RBD design with five replications. The plant arrangement was rectangular in which the spacing between the rows was maintained as 22 feet. The spacing within a row varied from 7 to 12 feet in different densities (Dey, 2019). Six densities comprised 408 trees ha^{-1} (22′ x 12′), 445 trees ha^{-1} (22′ x 11′), 489 trees ha^{-1} (22′ x 10′), 554 trees ha^{-1} (22′ x 9′), 613 trees ha^{-1} (22′ x 8′), and 699 trees ha^{-1} (22′ x 7′). Other cultural practices were done as per the package of practices recommendations of the Rubber Board. The number of plants accommodated in a plot was 24 in four rows at all densities. The tapping was initiated during April 2014 and trees were tapped in S/2 d3 6d/7 system of tapping. The trees were rainguarded and ethephon at 2.5 per cent a.i. was applied three times in a year (Pa 3Y) for yield stimulation and tapping was continued round the year without rest. The yield of individual trees was recorded following cup coagulation method. Tree girth at a height of 150 cm from bud union was measured annually. Plant height, crotch height, major branch number and bark thickness were measured at the 14th year of planting. The thickness of virgin bark was measured using a bark gauge. Bole volume was estimated by using the equation

$$V= (G/4)^2 \times H$$

(Chaturvedi and Khanna, 1982)

where V is the bole volume (m^3), G is the girth (m) and H is the bole height (m).

Benefit-Cost Ratio (BCR) and Internal Rate of Return (IRR) were estimated based on the expenditure in immature and mature phase of the plantation and income from seven years of dry rubber yield.

RESULTS AND DISCUSSION

The growth curve of clone RRII 429 for a period of 14 years is presented in Figure 1. Tree girth was found to be higher at lower plant densities in comparison to high plant densities. The growth of tree during immature phase was not significantly affected by the different densities up to five years after planting (Dey, 2019). The girth (71.2 cm) at the lowest density (408 trees ha^{-1}) continued to be higher throughout the growth period. Similar results were reported in traditional (Philip *et al*., 2014) and non-traditional region of India (Dey and Datta, 2013).

There was significant effect of planting density on crotch height. Crotch height or bole height increased with increase of plant density (Table 1). Trees in the highest density (699 trees ha^{-1}) recorded higher bole height than the trees in the lowest density (408 trees ha^{-1}). The clear bole volume per tree was not significantly affected by different densities. Reduction in girth and increase in bole height with increase of density may lead to a comparable bole volume of a tree in different densities. There was no significant difference in height gain under different densities, however taller plants (20.9 m) were observed in the highest density (699 trees ha^{-1}) than in the lowest (18.7 m) density (408 trees ha^{-1}) 14 years after planting. Denser planting resulted in narrower crown and higher crotch height (Webster 1989; Philip *et al*., 2014). Planting density had significant effect on bark thickness. The density of 409 trees ha^{-1} had thicker bark compared to the density of 699 trees ha^{-1} (Table 1). Trees in the lowest density had higher bark thickness (6.4 mm) among the various densities. Similar trend has been reported in the traditional region (Varghese *et al*., 2006) and non-traditional region of India (Dey and Datta, 2013). Thinner virgin bark under higher planting density has been reported from Sri Lanka (Rodrigo *et al*., 1995) and Malaysia (Ng, 1993) as well. The effect of planting density on the proportion of small trees is very apparent (Table 1). The percentage of small trees, which

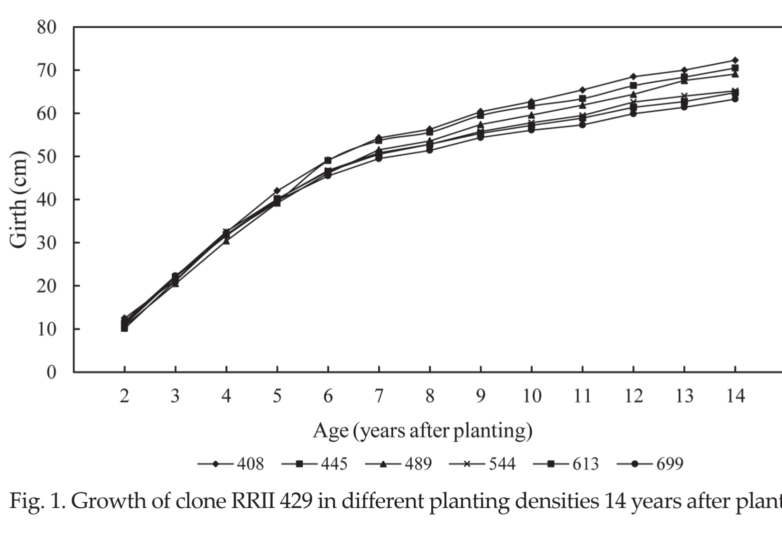

Fig. 1. Growth of clone RRII 429 in different planting densities 14 years after planting

Table 1. **Girth, crotch height, bole volume, bark thickness and TPD incidence at different planting densities**

Density (trees ha^{-1})	Girth (cm)	Crotch height (m)	Clear Bole Volume (m^{-3} $tree^{-1}$)	Bark thickness (mm)	TPD (%)
408	71.2	2.56	0.08	6.4	5.2
445	69.0	2.66	0.08	6.0	5.6
489	67.8	2.78	0.08	5.7	7.2
544	64.7	2.85	0.07	5.4	7.4
613	64.0	3.01	0.08	5.1	11.4
699	62.4	3.32	0.08	5.0	13.7
Mean	66.5	2.86	0.08	5.6	8.41
CD (P<0.05)	5.8	0.22	NS	0.5	1.95

are not suitable for tapping, known as runts was 1.2 for the lowest density (409 trees ha^{-1}) and 12.7 for the highest density (699 trees ha^{-1}). Due to the availability of space, the low density populations produced more branches. Though branch number was not significant (Table 1), higher number of main branches was observed in lower density (3.3) compared to the higher density (2.7).

Planting density had significant effect on tree productivity (g t^{-1} t^{-1}) of rubber throughout the yielding phase. There was a decreasing trend in yield per tree with increase in plant density. During the initial two years of tapping, yield per tree was not significantly influenced by the density (Table 2). However, in the subsequent years, plants in the highest density (699 trees ha^{-1}) recorded significantly lower yield per tree than the trees in all other densities. Higher average yield per tree per tap (52 g t^{-1} t^{-1}) over seven years was observed in the lowest density (408 trees

Table 2. **Yield (g t^{-1} t^{-1}) at different planting densities**

Density (trees ha^{-1})	Year of tapping (g t^{-1} t^{-1})						
	1st	2nd	3rd	4th	5th	6th	7th
408	27.3	34.1	41.9	53.5	57.2	67.3	83.0
445	26.4	33.2	41.8	52.9	56.7	65.5	82.0
489	26.4	32.2	40.2	51.5	55.3	64.2	80.2
544	26.9	32.8	40.8	51.6	54.9	63.9	79.8
613	23.7	31.0	37.7	48.2	52.8	59.9	76.4
699	22.9	28.8	36.2	43.6	49.5	54.4	70.2
Mean	25.6	32.0	39.8	50.2	54.4	62.5	78.6
CD (P<0.05)	NS	NS	4.0	6.7	4.9	7.5	7.9

ha^{-1}) compared to the highest density. Higher yield per tree in lower planting density is in conformity with the earlier reports (Ng, 1993; Dey and Pal, 2006; Pathiratna *et al*., 2006; Philip *et al*., 2014). Lower girth and thinner bark in high density planting resulted in low yield per tree. Tapping Panel Dryness (TPD) is a bark disorder and plants grown at high densities are often more susceptible to TPD (Table 1). High incidence of TPD (13.7%) was encountered in the highest density compared to the lowest density (5.2%).

In general, the annual yield per hectare increased with the increase in planting density. Density of planting indicated that with increase of density, yield per hectare increased due to the higher number of tappable trees. In seventh year, 360, 353, 357, 381, 395 and 480 numbers of trees were tapped in the 408, 445, 489, 544, 613 and 699 trees ha^{-1} densities respectively. The seven year yield data showed that it was significantly higher in the higher densities and was comparable among the densities of 544, 613 and 699 trees ha^{-1} (Table 3). In first year it was highest in the highest density, 699 trees ha^{-1}. Higher number of tappable trees ha^{-1} in higher densities leads to higher yield per hectare in the subsequent years. The mean yield of seven years showed that the highest (1912 kg ha^{-1}) yield was recorded in the planting density 613 trees ha^{-1} and it was on par with that of the highest density 699 trees ha^{-1} (1882 kg ha^{-1}). These results were in line with the studies by Philip *et al*. (2014) and Dey and Datta, (2013).

The planting density represents growing space of planted trees. Less growing space is available for trees in the denser planting density. It is obvious that high planting density resulted in the production of greater percentage of runts compared to low densities. The total number of tapping trees increases with the increase in planting density, however, the percentage of trees under tapping in higher densities is less than that of low densities (Silva *et al*., 2007). Most experiments showed a decline in per tree yield but an increase in per hectare yield with increase in planting density (Tiong *et al*., 1994) up to certain density. Yield per hectare varied relatively little over quite a wide range of planting densities (Webster, 1989). It has been reported from different countries that the optimum plant density to get high

Table 3. **Yield (kg ha^{-1} yr^{-1}) at different planting densities**

Density	Year of tapping (kg ha^{-1} yr^{-1})							
(trees ha^{-1})	1st	2nd	3rd	4th	5th	6th	7th	Mean
408	953	1188	1413	1808	1769	1638	1701	1496
445	904	1179	1536	1969	1935	1760	1836	1588
489	914	1196	1520	2049	1993	1937	2065	1668
544	994	1329	1702	2250	2188	2253	2403	1874
613	947	1354	1705	2229	2258	2364	2524	1912
699	935	1327	1722	2243	2202	2260	2475	1881
Mean	941	1262	1599	2091	2057	2035	2167	1737
CD (P<0.05)	NS	NS	209	278	191	287	211	169

Table 4. **Economic analysis for different planting densities**

Density (trees ha^{-1})	Expenditure*	Income*	BCR**	IRR* (%)
408	756908	1539857	2.03	24.83
445	774883	1628686	2.10	25.25
489	804690	1702281	2.11	25.31
544	858160	1908944	2.22	26.49
613	925693	1939958	2.09	25.02
699	990241	1911266	1.93	23.11

*Discounted value (9%)

**The estimates are based on 7 years yield data

productivity for rubber can range from 500 to 700 plants ha^{-1} (Zongdao and Xaegin, 1983; Ng *et al.*, 1993; Jarin and Somyot 1996; Obouayeba *et al.*, 2005; Rodrigo, 2007). Optimum density of 549 trees ha^{-1} has been reported for traditional rubber growing region of India for clone RRII 105 (Philip *et al.*, 2014) and 613 trees ha^{-1} for non-traditional region for clone RRII 105 and RRII 118 (Dey and Datta, 2013).

Economic analysis was carried out for the different planting densities (Table 4). Cumulative cash flow over the 14 year period showed differences among the six densities. The returns was the highest from the density of 544 trees ha^{-1}. Negative cash flow is much greater for 699 trees ha^{-1}. Based on this analysis, a planting at 699 trees per hectare would be feasible but would offer no economic advantage over moderate densities. The results of the present analysis indicated that a density ranging from 544 to 613 trees per hectare is optimum for planting rubber. Benefit-cost ratio (BCR) would be higher in high densities if family labour is used for tapping activities under small holding conditions. Considering the cost of cultivation, tapping and income from yield of seven years, planting density of 544 trees ha^{-1} gave the highest BCR and IRR indicating that it is the best possible planting option for North East India.

Plant population is one of the factors affecting growth and yield. Increasing productivity per hectare through tree management is one of the important strategies to increase production of latex yield of rubber. Additional advantage in rectangular spacing is that more space is available in between rows. Intercropping with short duration crops provides an opportunity to utilize those space enabling farmers to earn extra income during the immature period of rubber. High land productivity of rubber has been on demand for the sustainability of the crop. Our study showed that increased density of rubber resulted in smaller girth, lower bark thickness, higher crotch height, less branching and low yield per tree. Having a larger number of trees ha^{-1} also means greater expenditure towards planting materials, planting and upkeep, both during the immature and mature stages. Cost of tapping and labour requirement are also high when there is more number of trees ha^{-1}. The standard density for planting of rubber recommended by Rubber Board is 420 to 500 tree ha^{-1} irrespective of genotype of rubber for the traditional region. However, for clone RRII 105 the density can be up to 550 trees ha^{-1} (Rubber Board, 2019). In our observation, the growth of rubber plant was not significantly affected by increasing density of planting from 544 to 613 trees ha^{-1}. However, a density of 544 trees ha^{-1} appears to be economically sustainable for Northeastern region of India.

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