Research Article

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High density planting in rubber plantations: Effect on growth and yield

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Abstract

Planting density is an important parameter influencing the growth and yield of trees. A field study was conducted at Central Experiment Station of Rubber Research Institute of India, Chethackal, Kerala with clone RRII 105 in split plot design with five densities as main plot treatments and two fertilizer quantities as sub plot treatment replicated four times to study the effect of density of planting on growth and yield of rubber. The five densities tested are 420 trees ha^{-1} (4.9 m x 4.9 m), 479 trees ha^{-1} (4.6 m x 4.6 m), 549 trees ha^{-1} (4.3 m x4.3 m), 638 trees ha^{-1} (4 m x 4 m) and 749 trees ha^{-1} (3.7 m x 3.7 m) and the two subplot treatments are recommended dose of fertilizer (RDF) on unit area basis and RDF on per plant basis. Growth of the plants was not significantly influenced by the different planting densities up to eighth year after planting, but in the later years increased planting density decreased the girth and trees in the lowest density of 420 trees ha^{-1} recorded significantly higher girth. The lowest density also recorded significantly higher per tree yield. However, the annual yield per hectare was the highest (2553 kg) in the highest density of 749 trees ha^{-1} which was comparable (2457 kg) with that of the density of 549 trees ha^{-1}. Bole height increased with planting density. But the bole volume, 18 years after planting was not significantly influenced by the planting density. Bark thickness was the highest (9.76 mm) in the lowest density and it was comparable (9.40) with that of the density 549 trees ha^{-1}. Effect of fertilizer application on per plant basis and area basis was not significant throughout the study period. Based on 7 years yield data highest BCR of 3.16 and IRR of 29.11 per cent were obtained for the density of 549 trees ha^{-1}.

Keywords: Girth, planting density, rubber, yield

Introduction

Rubber (*Hevea brasiliensis*) plays an important role in Indian economy. India is the fourth largest producer of natural rubber in the world. The demand of natural rubber is increasing and in order to meet this, land productivity has to be increased. Apart from the use of high yielding clones, increasing the planting density is a way to achieve this. In India, 89 per cent of the area under rubber cultivation is in the small holding sector. Small holdings resort to high density planting to increase the production per unit area. However, increasing planting density beyond an optimum may lead to poor growth, yield and less net income. An ideal density is one which gives enough above and below ground space for all the trees to grow without competition for sunlight, nutrients and water. Density determines the yield per tree and per unit area besides influencing the planting, maintenance and tapping cost. Thus planting density is important in rubber cultivation.

Even though high tree densities reduce the growth and per tree yield (g t^{-1}t^{-1}) of rubber, higher yield per hectare is obtained in higher density (Obouayeba *et al*., 2005). Studies in Sri Lanka showed that trees under lower densities of 400 and 533 trees ha^{-1} performed better than those under higher densities (Pathiratna *et al.*, 2006). Dey and Pal (2006) reported that in North Eastern India, optimum planting density of clone RRII 105 and RRII 118 was 606 trees ha^{-1}. The present recommended planting density for rubber in India is 420-500 trees ha^{-1}. In order to understand the effect of increased plant density on growth and yield of rubber in the traditional rubber growing tract in

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India, a field study was conducted at Central Experiment Station of Rubber Research Institute of India, Chethackal and the data collected up to the 18th year of planting are discussed.

Materials and methods

The experiment was initiated at Central Experiment Station, Chethackal during 1994 with clone RRII 105 in split plot design with five densities as main plot treatments and two fertilizer quantities as sub plot treatments replicated four times. The five densities in the main plot comprises 420 trees ha^{-1} (4.9 m x 4.9 m), 479 trees ha^{-1} (4.6 m x 4.6 m), 549 trees ha^{-1} (4.3 m x 4.3 m), 638 trees ha^{-1} (4 m x 4 m) and 749 trees ha^{-1} (3.7 m x 3.7 m) and the two subplot treatments are recommended dose of fertilizer (RDF) on unit area basis (F_1) and RDF on per plant basis (F_2). The RDF for rubber in the initial four years is as follows: 10:10:4:1.5 NPKMg mixture @ 450, 900, 1100 and 900 g $plant^{-1}$ $year^{-1}$. From 5th year onwards the RDF is 30:30:30 kg NPK per ha. Urea, rock phosphate, muriate of potash and magnesium sulphate were the fertilizers used. The plot size ranged from 25 to 49 plants according to the density. Soil of the experimental area had a pH of 5.02 and was found to be high in organic carbon (2.42%) and available magnesium (3.63 mg per 100 g), medium in available phosphorus (1.80 mg per 100 g) and potassium (7.25 mg per 100 g). The experiment station received annual rainfall ranging from 2793 mm to 4560 mm during the study period. Girth of plants at a height of 150 cm from bud union was recorded annually. Tapping was initiated in 2003 adopting S/2 d3 system. The yield of individual tree was recorded at fortnightly intervals following cup coagulation method. Soil samples were collected during 2011 and analysed for soil chemical properties following standard procedures (Jackson, 1973). Bark thickness and bole height were measured 18 years after planting. Bole volume was worked out 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). BCR and IRR were estimated based on the expenditure in the immature and mature phase of the study and income from 7 years latex yield.

Results and discussion

Results from the trial in the immature phase of growth indicated that girth of the plants was not significantly influenced by the different densities up to eight years after planting (Varghese *et al.*, 2006). Contrary to this in the later years, girth of plants in the lowest density of 420 trees ha^{-1} was found to be significantly higher than that of all other planting densities and this superiority was maintained throughout the study period. The lowest girth was recorded in the highest density plot (Table 1). Low girth under high planting density of rubber was reported by Dey and Pal (2006) and Pathiratna *et al.* (2006). The better growth in the lower density might be due to the comparatively lesser competition for nutrients, sunlight and moisture.

Table 1. Girth (cm) of plants at different planting densities

	Year								
Treatments	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Density (D) (trees ha^{-1})									
420	59.20	62.98	65.99	67.93	68.29	69.74	71.63	73.33	74.76
479	55.17	57.31	59.11	60.58	61.91	63.31	64.10	65.15	65.87
549	55.50	58.36	60.41	62.17	63.02	64.62	65.59	66.80	67.75
638	53.31	55.80	57.35	59.06	60.14	61.70	63.30	64.41	65.41
749	52.41	54.50	56.28	57.55	58.46	59.92	61.16	62.56	63.79
Fertilizer F_1	55.50	58.07	60.26	61.90	63.08	64.60	65.83	65.95	68.15
(F) F_2	54.74	57.50	59.39	61.03	61.60	63.07	64.48	65.19	66.88
CD (0.05) (D)	2.14	1.81	1.70	2.10	2.20	2.39	2.41	3.31	3.94
CD (F)	NS								
CD (DxF)	NS								

NS- Not significant

Bark thickness of trees (18 years after planting) was affected by the different planting densities and fertilizer treatments (Table 2). Trees in the lowest density had significantly higher bark thickness (9.76 mm) among the various densities and it was comparable with that (9.40 mm) in the density at 549 trees ha^{-1}. The lowest bark thickness (8.71 mm) was recorded in the highest density. Pathiratna *et al.* (2006) also reported low bark thickness in high density planting. Bark thickness of trees receiving fertilizer dose on unit area basis was significantly higher than that of trees receiving fertilizer dose on per plant basis indicating that there is no advantage of additional fertilizer. Light is the most limiting factor for growth of mature crop with a closed canopy rather than applied nutrients (Rodrigo, 2007).

Table 2. Bark thickness at different planting densities (18 years after planting)

Treatments	Bark thickness (mm)
Density (trees ha^{-1})	
420	9.76
479	9.27
549	9.4
638	9.04
749	8.71
Fertilizer (F)	
F_1	9.39
F_2	9.1
CD (D) 0.37	
CD (F) 0.19	
CD (DxF) NS	

NS- Not significant

Tapping commenced during 2003 and recorded the yield for 7 years (Yield recording was not carried out during the fifth year due to labour strike). The tappability percentage (2003) of the five densities *viz*. 420, 479, 549, 638 and 749 trees ha^{-1} was 70, 67, 61, 60 and 47 respectively (Varghese *et al.*, 2006). In the first year of tapping, per tree yield was not significantly influenced by the different densities (Table 3). However, in the subsequent years, plants in the lowest density (420 trees ha^{-1}) recorded significantly higher per tree yield (g $t^{-1}t^{-1}$) than all other densities. Higher yield per tree in lower planting density is in conformity with earlier reports (Ng, 1993; Dey and Pal, 2006; Pathiratna *et al.*, 2006). Lower girth and thinner bark in high density planting resulted in low yield per tree.

The annual yield per hectare showed a different trend. In general, it increased with the planting density. The seven year yield data (Table 4) showed that in four years it was significantly higher in the highest density and it was comparable with that of the density 549 trees ha^{-1}. In two years it was highest in the density 549 trees/ha^{-1}. In the 8^{th} year of tapping 320, 400, 478, 511 and 594 trees were tapped in the densities 420, 479, 549, 638 and 749 trees ha^{-1} respectively. More number of tappable trees ha^{-1} in higher densities leads to higher yield per hectare. The mean yield of seven years was also the highest

Table 3. Yield (g $t^{-1}t^{-1}$) at different planting densities

Treatments	Year of tapping						
	1^{st}	2^{nd}	3^{rd}	4^{th}	6^{th}	7^{th}	8^{th}
Density (D) (trees ha^{-1})							
420	50.8	61.3	65.6	80.4	69.0	100.0	78.8
479	46.4	51.1	50.6	59.0	49.7	70.5	64.8
549	49.4	55.1	51.7	62.8	45.5	73.5	71.9
638	47.0	48.1	46.7	56.9	41.4	68.0	53.5
749	45.5	45.5	43.3	55.3	40.6	57.5	55.1
Fertilizer (F)							
F_1	48.4	53.2	52.7	63.7	51.2	78.5	66.1
F_2	47.3	51.1	50.4	62.0	47.3	70.0	63.5
CD (0.05) (D)	NS	7.8	7.6	9.2	10.3	10.3	5.1
CD (F)				NS			
(DxF)				NS			

NS- Not significant

Table 4. Yield (kg ha^{-1} year^{-1}) at different planting densities*

Treatments	Year of tapping							Mean yield
	1st	2nd	3rd	4th	6th	7th	8th	(7 years)
Density (D) (trees ha^{-1})								
420	965	1549	1776	2101	1508	3249	2649	1858
479	1133	1785	1863	2166	1703	2853	2724	2041
549	1354	2214	2333	2592	1845	3508	3607	2457
638	1441	2138	2110	2675	1973	3518	2867	2283
749	1170	2070	2143	2703	2119	3660	3433	2553
Fertilizer (F)								
F_1	1264	2045	2138	2479	1884	3445	3081	2236
F_2	1161	1858	1952	2416	1775	3270	3032	2241
CD (0.05) (D)	316.1	418.8	NS	283.12	227.18	608.38	409.09	284.38
CD (F)				NS				
(DxF)				NS				

*Yield calculation is based on the actual number of tapped trees in each year and 105 tapping days annually except for the first year (86 days); NS – Not significant

(2553 kg ha^{-1}) in the highest density and it was on par with that of 549 trees ha^{-1} (2457 kg ha^{-1}).

Bole height increased with increase in planting density (Table 5). Trees in the highest density (749 trees ha^{-1}) recorded significantly higher bole height than that of the lowest density (420 trees ha^{-1}) but comparable with those of other three densities. At higher densities there was competition for sunlight and trees undergo certain modifications such as increase in height. The trees tend to grow taller and thinner in order to harvest more sunlight (Webster, 1969). Apart from latex, rubber wood is a major by-product in enhancing the net farm income (Viswanathan *et al*., 2002). It was observed that bole volume (18 years after planting) was not significantly influenced by the different densities. Both the reduction in girth and increase in bole height with increase of density may lead to a comparable bole volume of the trees under different planting densities ranging from 420-749 trees ha^{-1}.

Table 5. Bole height and bole volume 18 years after planting

Treatments	Bole height (m)	Bole volume (m^3)
Density (D) (trees ha^{-1})		
420	2.89	0.099
479	3.11	0.103
549	3.25	0.105
638	3.33	0.095
749	3.41	0.098
Fertilizer (F)		
F_1	3.17	0.1
F_2	3.22	0.1
CD (00.5) (D)	0.49	NS
CD (0.05) (F)	NS	NS
DxF	NS	NS

NS- Not significant

Soil properties 18 years after initiation of the study was not significantly influenced by the treatments and the mean values are given in the Table 6. It was observed that organic carbon and available Mg continued to be in the high range and available P and K in the medium range. However, soil pH decreased from 5.02 to 4.61 after 18 years.

It was also noticed that fertilizer treatments had no significant effect on girth and yield throughout the study period. This is in conformity with that reported by Dey and Pal (2006). The lack of response to applied fertilizers may be due to the medium to high level nutrient status of the experimental field. The lesser influence of applied nutrients on the growth of mature crop with a closed canopy than the light (Rodrigo, 2007) may also leads to this effect.

Table 6. Soil chemical properties 18 years after initiation of the study

OC (%)	Available nutrients (mg per 100 g)			pH
	P	K	Mg	
2.54 (2.42)	1.28 (1.80)	9.06 (7.25)	2.79 (3.63)	4.61 (5.02)

Figures in parenthesis are initial soil status

Table 7. Economic analysis for different planting densities

Density (trees ha^{-1})	Expenditure* (Rs)	Income* (Rs)	BCR**	IRR (%)*
420	147845	394745	2.67	27.21
479	156947	423757	2.70	27.27
549	169467	535514	3.16	29.11
638	178901	495556	2.77	27.48
749	189870	527840	2.78	27.15

* Discounted values (9%)

** The estimates are based on 7 years yield data

Economic analysis was carried out for the different planting densities (Table 7). Considering the cost of cultivation and tapping and income from latex yield of 7 years, planting density of 549 trees ha^{-1} gave the highest BCR and IRR indicating that it is the best investment option.

The study showed that increasing planting density significantly reduced the girth of rubber and per tree yield. Bole volume was not affected by the planting density. The yield per unit area increased with the planting density and the optimum planting density of clone RRII 105 was 549 trees ha^{-1}.

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