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Performance of rice cultivar CR Dhan 307 (Maudamani) as influenced by different planting densities in *terai* zone of West Bengal

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Abstract
A field experiment was carried out during *kharif* season of 2018 at Pundibari, Coochbehar, West Bengal, to study the influence of different planting densities on the growth and yield of a heavy panicle rice cultivar CR Dhan 307 (Maudamani). The experiment was laid out in a randomized complete block design with three replications. Although transplanting of rice seedlings with the density of 15 cm × 15 cm did not produce the highest number of tillers m^{-2} but registered the highest dry matter accumulation during the period of observation. Crop growth rate at 30-60 days after transplanting was found the highest under the spacing of 15 cm × 15 cm. But crop growth rate recorded under this treatment at 60-90 days after transplanting was statistically *at par* with the highest result obtained on that day of observation. Plant height at 90 days after transplanting under the spacing of 15 cm × 15 cm was also statistically *at par* with the maximum plant height obtained at 90 days after transplanting. Among the yield attributing characters, number of panicles m^{-2} under rice transplanting with the spacing of 15 cm × 15 cm was statistically *at par* with the maximum number of panicles m^{-2} (15 cm × 10 cm) recorded. Other major yield attributing characters (*i.e.*, total number of grains $panicle^{-1}$ and number of filled grains $panicle^{-1}$) were found the highest under the planting density of 15 cm × 15 cm being significantly different from the other treatments. As an obvious effect of obtaining higher results in most of the growth and yield attributes, rice transplanting with the spacing of 15 cm × 15 cm showed maximum grain yield, grain-straw ratio and harvest index. In case of production economics, highest gross return, net return, input-output ratio and incremental cost-benefit ratio under the spacing of 15 cm × 15 cm described the superiority of this planting density for rice cultivar CR Dhan 307.

Keywords: Growth, planting density, rice, yield

Introduction

Rice (*Oryza sativa* L.) is the most important cereal crop in the world. It is the primary source of food for more than one third of the global population, especially in Asia, Africa and Latin America (Hasamuzzaman *et al.,* 2009) [8]. It is the second most widely consumed cereal crop after wheat. It is cultivated in about 11% of the world's cultivated area (Islam *et al.*, 2009) [8]. It contains many energy rich compounds such as carbohydrates, fats, proteins, reasonable amounts of vitamins like thiamine, riboflavin and niacin and minerals like iron, calcium (Juliano, 1993) [11].

Asia is the leading producer of rice accounting for about 90% of the world's total production. More than 75% of the world's supply is consumed by the peoples of Asian countries. Thus, rice is of paramount importance to the food security of Asia. China is the leading producer of rice followed by India among all the countries in the world. Rice occupies very important place in Indian agriculture and is the staple food for more than 65% of the Indian population, accounting for more than 43% of the total food grain production and 55% of the total cereal production of the country. India shares around 21% of the global rice production from about 28% of the global rice area. Rice plays a vital role in the food and livelihood security of millions of the rural households of India.

According to the report of Directorate of Economics & Statistics, DAC&FW (2017) [6], rice is grown in India in an area of about 43.50 mha with an annual production of about 104.41 mt. However, the average rice productivity in India is only about 2.40 t ha^{-1} against the global average rice productivity of 3.28 t ha^{-1} (Anonymous, 2015). Considering the current rate of increasing population of India, the supply projection falls short of the expected demand of 121.6 mt by the year 2030 and 137.3 mt by the year 2050. In order to achieve the target yield, adoption of improved rice production technology is essential (Anonymous, 2011) [1]. In India, the leading rice growing states are West Bengal, Andhra Pradesh, Uttar Pradesh, Punjab, Assam, Bihar, Tamil Nadu, Chhattisgarh, Odisha and Haryana. More than 70% of India's rice area is confined to these states. West Bengal, Uttar Pradesh and Punjab are three leading states in rice production (DES, 2016). West Bengal occupies second position in terms of area (5.46 mha *i.e.*, 12.59% of the total rice area of India) and first position in terms of production (15.75 mt *i.e.*, 15.10% of the total rice production of India) with an average productivity of 2.88 t ha^{-1} (DES, 2016). In West Bengal, rice is grown in three seasons *viz. Aus* or Pre-*Kharif* rice (March-April to August-September), *Aman* or *Kharif* rice (June-July to October-November) and *Boro* or Summer rice (December-January to April-May). *Aman* rice is the most pre-dominant among them. *Aman* rice occupies about 75% of the total area under rice cultivation in West Bengal. The annual average productivity of rice in Coochbehar district of West Bengal during *kharif* season was 2.38t ha^{-1} in 2014-15 (Statistical Abstract, BAE&S, 2015) [19] which was lower than average annual productivity of the state as well as the national average annual productivity. In such situation, use of some high yield potential cultivars is necessary to improve the rice productivity of Coochbehar district. CR Dhan 307 (Maudamani) is one such cultivar which can show positive results in this aspect by virtue of its heavy panicles and high density planting adaptability.

Appropriate agronomic management practices are basic pre-requisites to use the full potential of a crop cultivar. Among the various available technologies, planting density plays a very significant role in optimizing the grain yield of rice. Closer spacing not only hampers intercultural operations, it also leads to more competition among the plants for resources like nutrients, water, light, space etc. as a result of which the plants becomes weaker and provide lower yield. It was experimentally found that increasing or decreasing the plant population from optimum, results inability of the plants to intercept the maximum available solar radiation (Mahajan *et al.,* 2009) [12]. Plant spacing or planting density helps in determining the stand count of rice per unit area. The spacing between row to row and plant to plant is an important agronomic practice that affects the growth and yield attributing characters as well as the quality of rice (Sultana *et al.,* 2012) [20]. Yield potential of rice cultivars varies with effective utilization of solar radiation, soil moisture and nutrient uptake from the soil and all these factors depend on the selection of appropriate plant spacing or planting density. At higher planting density, these factors may be deficient while at lower planting density, these factors may not be properly utilized. Planting density or spatial configuration can help in exploiting the initial vigour of the rice genotypes with enhanced soil aeration and creating a congenial condition for better establishment of the crop (Shukla *et al.*, 2014) [18]. An appropriate planting density can also help in reducing the seed requirement in sowing operation without sacrificing the productivity thus helping in reducing the cost of rice cultivation.

Materials and Methods

The field experiment was carried out during *kharif*, 2018 on sandy loam soil at Agricultural Research Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar located at 26°19'86"N latitude, 89°23'53"E longitude and at an elevation of 43 meters above mean sea level (MSL). The soil was sandy loam in texture. Initial soil pH was 6.15 (slightly acidic), available N, P_2O_5 and K_2O were 126.35 kg ha^{-1} (low), 29.67 kg ha^{-1} (low) and 101.69 kg ha^{-1} (low), respectively. The rice cultivar used in this experiment was CR Dhan 307 (Maudamani) which was a long duration cultivar (135-145 days). The seed rate was 35 to 40 kg ha^{-1} in nursery bed and transplanting was done in the main field at 30 days after sowing (DAS) with 2 seedlings hill^{-1}. The experiment was designed in randomized complete block design. Four different planting densities were taken as four treatments which were replicated thrice and randomly allocated in the experimental plots. The recommended dose of fertilizers for transplanted rice in West Bengal during *kharif* season *viz.* 65 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1}, 40 kg K_2O ha^{-1}, 25 kg $ZnSO_4$ ha^{-1} were applied in the form of Urea, Single Super Phosphate (SSP), Muriate of potash (MOP) and Zinc sulphate mono hydrate, respectively. In the main field, one third N, full amount of P_2O_5, K_2O and $ZnSO_4$ were applied as basal. Rest 2/3rd N was applied in two equal splits as top-dressing *i.e.* 1/3rd N at 25 DAT and the rest 1/3rd N at 45 DAT. The crop growth rate during the period of two growth stages was determined by using the following formula proposed by Watson (1952) [22]:

$$\text{Crop growth rate (CGR)} = \frac{W_2 - W_1}{t_2 - t_1} \ \text{g m}^{-2}\text{day}^{-1}$$

Where,

W_1 and W_2 are plant dry weight per unit area (g m^{-2}) at time t_1 and t_2, respectively

The relative growth rate during the period of two growth stages was determined by using the following formula proposed by Blackman (1919) [3]:

$$\text{Relative growth rate (RGR)} = \frac{\ln W_2 - \ln W_1}{t_2 - t_1} \ \text{g g}^{-1}\ \text{day}^{-1}$$

Where,

W_1 and W_2 are plant dry weight (g) at time t_1 and t_2, respectively

'ln' is Natural logarithm ($\ln = \log_e Y = 2.303 \times \log_{10} Y$)

Harvest index (%) is calculated with the help of the following formula which was suggested by Donald and Hamblin (1976) [7]:

$$\text{Harvest Index (HI)} = \frac{\text{Grain yield}}{\text{Grain yield + Straw yield}} \times 100$$

Results and Discussion

Growth components

From Table 1, it was found that the highest plant height was recorded with rice transplanting at a spacing of 15 cm × 10 cm (136.38 cm) at 90 DAT which was statistically similar to rice transplanting at a spacing of 15 cm × 15 cm (135.62 cm) at 90 DAT. Transplanting of rice plants at a spacing of 20 cm × 20 cm provided lowest plant height at 90 DAT (128.68 cm). This result was corroborated by the previous report of Mobaseer *et al.* (2007) and Mahato *et al.* (2017) [14]. Maximum number of tillers m^{-2} was also recorded under 15 cm × 10 cm spacing (243.10, 300.75 and 250.63 at 30, 60 and 90 DAT, respectively) and minimum number of tillers m^{-2}

was found under 20 cm × 20 cm spacing (171.81, 214.28 and 185.57 at 30, 60 and 90 DAT, respectively) during all the dates of observation. Rasool *et al.* (2013) [16] reported that rice transplanted at closer spacing produced significantly higher number of tillers m^{-2} than the rice transplanted at wider spacing. The data pertaining to the dry matter accumulation (DMA) in rice at 30, 60 and 90 DAT showed significant difference under different planting densities (Table 1 and Fig. 1). During the period of observation, rice transplanted at a spacing of 15 cm × 15 cm showed the maximum DMA (325.25, 712.75 and 1335.40 g m^{-2} at 30, 60 and 90 DAT, respectively) which was statistically *at par* with rice transplanting at a spacing of 15 cm × 10 cm (299.24, 662.50 and 1334.63 g m^{-2} at 30, 60 and 90 DAT, respectively). DMA was recorded significantly lower under planting densities of 20 cm × 15 cm and 20 cm × 20 cm than the DMA under 15 cm × 15 cm spacing during all the dates. Rasool *et al.* (2013) [16] reported that closer spacing of 15 cm × 15 cm registered comparatively higher DMA than wider spacing of 15 cm × 20 cm and 20 cm × 20 cm. Rice transplanted at a spacing of 15 cm × 15 cm recorded the maximum CGR during 30-60 DAT (12.92 g m^{-2} day^{-1}) being statistically *at par* with the planting density of 15 cm × 10 cm (12.11 g m^{-2} day^{-1}) and 20 cm × 20 cm (11.99 g m^{-2} day^{-1}) but significantly higher from 20 cm × 15 cm (10.79 g m^{-2} day^{-1}). At 60-90 DAT, the rice crop transplanted with the density of 20 cm × 15 cm recorded the maximum CGR (20.95 g m^{-2} day^{-1}) being statistically *at par* with the planting densities of 15 cm × 15 cm (20.75 g m^{-2} day^{-1}) and 20 cm × 20 cm (19.38 g m^{-2} day^{-1}) but significantly higher from rice transplanted with the density of 15 cm × 10 cm (15.73 g m^{-2} day^{-1}). RGR was not significantly influenced by different planting densities during 30-60 DAT. But RGR was significantly differed due to different planting densities during 60-90 DAT (Table 1 and Fig. 2). The maximum RGR was recorded from the treatment where rice transplanted at a spacing of 20 cm × 15 cm (0.026 g g^{-1} day^{-1}) being statistically *at par* with the rice transplanted at a spacing of 20 cm × 20 cm (0.025 g g^{-1} day^{-1}) but significantly higher from the other treatments *i.e.*, and planting density of 15 cm × 15 cm (0.021 g g^{-1} day^{-1}) and planting density of 15 cm × 10 cm (0.018 g g^{-1} day^{-1}).

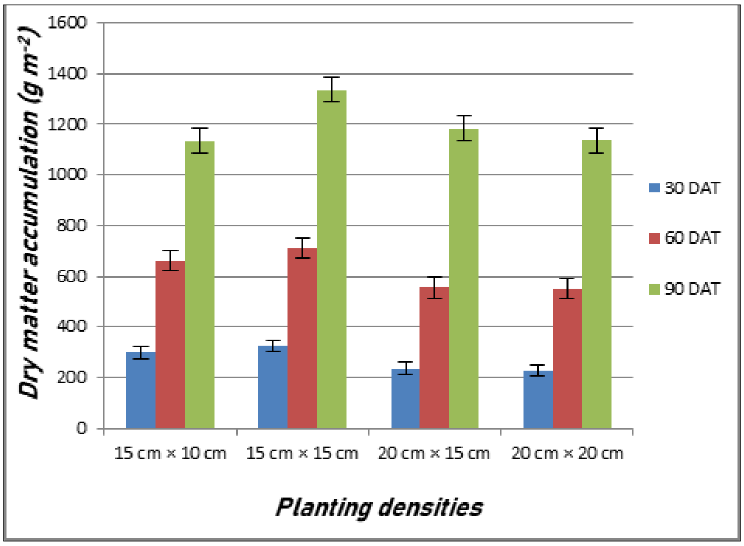

Fig 1: Effect of different planting densities on dry matter accumulation

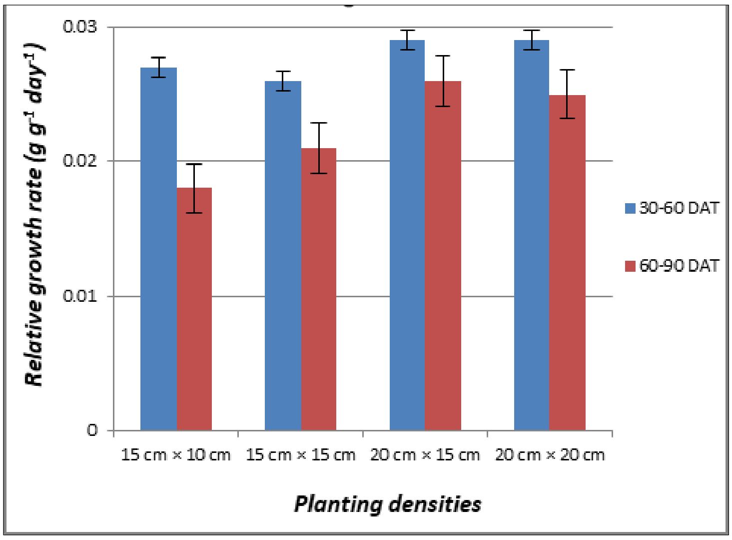

Fig 2: Effect of different planting densities on relative growth rate

Table 1: Effect of different planting densities on the growth attributing characters of the rice cultivar CR Dhan 307 (Maudamani)

Treatments (Planting densities)	Plant height at 90 DAT (cm)	Number of tillers m^{-2}			DMA (g m^{-2})			CGR (g m^{-2} day^{-1})		RGR (g g^{-1} day^{-1})	
		30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30-60 DAT	60-90 DAT	30-60 DAT	60-90 DAT
15 cm × 10 cm	136.38	243.10	300.75	250.63	299.24	662.50	1134.63	12.11	15.73	0.027	0.018
15 cm × 15 cm	135.62	212.33	262.67	222.89	325.25	712.75	1335.40	12.92	20.75	0.026	0.021
20 cm × 15 cm	131.26	184.61	230.11	197.76	235.12	554.26	1183.07	10.79	20.95	0.029	0.026
20 cm × 20 cm	128.68	171.81	214.28	185.57	227.12	553.63	1135.01	11.99	19.38	0.029	0.025
S. Em (±)	1.385	3.622	10.564	4.842	18.701	17.214	9.996	0.458	0.506	0.002	0.001
C.D. (P=0.05)	4.314	11.285	32.911	15.086	58.263	53.630	31.141	1.427	1.577	NS	0.002

Yield components

The longest panicles were found in the treatment where rice was transplanted at a spacing of 15 cm × 15 cm (24.39 cm). This was statistically *at par* with rice transplanted at a spacing of 20 cm × 15 cm (23.96 cm) and 20 cm × 20 cm (23.23 cm). The treatment, rice transplanted at a spacing of 15 cm × 10 cm recorded shortest panicles (21.36 cm) (Table 2). This was due to higher competition faced by the rice plants in closely spaced crop. Jena *et al.* (2010) [10] also reported that the rice crop transplanted at a spacing of 15 cm × 15 cm provided maximum length of panicles. Highest number of panicles m^{-2} was recorded with the rice transplanted at a spacing of 15 cm × 10 cm (217.94) being statistically *at par* with the rice transplanted at a spacing of 15 cm × 15 cm (210.14) but significantly higher from the rice transplanted at a spacing of 20 cm × 15 cm (186.95) and 20 cm × 20 cm (174.28). Previous report of Rautary *et al.* (2007) [17] regarding the highest number of panicles m^{-2} was supported this result. Total number of grains panicle^{-1} was recorded maximum from the treatment where rice transplanted with the density of 15 cm × 15 cm (270.49) being statistically *at par* with the treatment, rice transplanted with the density of 20 cm × 15 cm (257.44). The heavy panicle characteristics of this rice variety and transplanting with optimum spacing together led to such result. Rice transplanted with the density of 20 cm × 20 cm (249.31) and 15 cm × 10 cm (205.57) recorded significantly lower total number of grains panicle^{-1}. Similarly, the maximum number of filled grains panicle^{-1} was recorded with the treatment, rice transplanted at a spacing of 15 cm × 15 cm (215.44) being statistically *at par* with the treatment, rice transplanted at a spacing of 20 cm × 15 cm (202.24). Rice transplanted with a spacing of 15 cm × 10 cm (154.63) and 20 cm × 20 cm (195.77) recorded significantly lower number of filled grains panicle^{-1}. Rasool *et al.* (2013) [16] reported earlier that panicle length, total number of grains panicle^{-1} and number of filled grains panicle^{-1} of rice were significantly influenced by different spacing between rows and plants. 1000-grain weight being a genetic character was not significantly influenced by different planting densities.

Table 2: Effect of different planting densities on the yield attributing characters of the rice cultivar CR Dhan 307 (Maudamani)

Treatments (Planting densities)	Panicle length (cm)	No. of Panicles (m^{-2})	Total grains Panicle^{-1}	Filled grains panicle^{-1}	1000 grain weight (g)
15 cm × 10 cm	21.36	217.94	205.57	154.63	21.21
15 cm × 15 cm	24.39	210.14	270.49	215.44	21.47
20 cm × 15 cm	23.96	186.95	257.44	202.24	21.31
20 cm × 20 cm	23.23	174.28	249.31	195.77	21.33
S. Em (±)	0.627	8.486	5.668	4.500	0.165
C.D. (P=0.05)	1.953	26.438	17.657	14.020	NS

Yield, grain-straw ratio and harvest index

Among all the treatments, the highest grain yield (6.89 t ha^{-1}) was obtained from the treatment where rice was transplanted at a spacing of 15 cm × 15 cm (Table 3 and Fig. 3). Bozorgi *et al.* (2011) [4] reported earlier that planting with a spacing of 15 cm × 15 cm produced the highest grain yield of rice. This treatment differed significantly from all other treatments in case of grain yield. Rice transplanted at a spacing of 20 cm × 15 cm, 20 cm × 20 cm and 15 cm × 10 cm showed the grain productivity of 5.84 t ha^{-1}, 5.36t ha^{-1} and 5.26 t ha^{-1}, respectively. These three planting densities were statistically *at par* with respect to grain yield of rice. Mahato *et al.* (2007) [13] and Rasool *et al.* (2013) [16] documented similar findings regarding the influence of different spacing on grain yield of rice. The highest straw yield (8.63 t ha^{-1}) was acquired from the treatment, rice transplanted at a spacing of 15 cm × 15 cm (Table 3 and Fig. 4). This planting density treatment differed significantly from all the other treatments. Rice transplanted at a spacing of 20 cm × 15 cm (7.67 t ha^{-1}) was statistically *at par* with the rice transplanted at a spacing of 20 cm × 20 cm (7.50 t ha^{-1}) and rice transplanted at a spacing of 15 cm × 10 cm (7.45 t ha^{-1}). Mahato *et al.* (2007) [13], Uddin *et al.* (2010) [21] and Bozorgi *et al.* (2011) [4] reported likewise. These results revealed that closer spacing produced significantly higher grain and straw yield as compared to wider spacing and very closer spacing. Among all the treatments, significantly highest biological yield was obtained from rice transplanting with a spacing of 15 cm × 15 cm (15.52 t ha^{-1}). Similar result was reported previously by Uddin *et al.* (2010) [21]. The rice crop transplanted at a spacing of 15 cm × 10 cm showed the lowest biological yield (12.71 t ha^{-1}). The data presented in Table 3 depicted that the grain-straw ratio varied from a maximum of 0.80:1 in the rice crop transplanted at a spacing of 15 cm × 15 cm to a minimum of 0.71:1 in the rice crop transplanted at the spacing of 15 cm × 10 cm and 20 cm × 20 cm, both. Similarly, the maximum harvest index was recorded with the rice transplanting at a spacing of 15 cm × 15 cm (44.40%) and it was closely followed by the rice transplanted at a spacing of 20 cm × 15 cm (43.22%) as mentioned in Table 3. The lowest harvest index was recorded with the treatment where rice was transplanted at a spacing of 15 cm × 10 cm (41.37%).

Table 3: Effect of different planting densities on grain yield, straw yield, biological yield, grain-straw ratio and harvest index of the rice cultivar CR Dhan 307 (Maudamani)

Treatments (Planting densities)	Yield (t ha^{-1})			Grain: Straw	Harvest index (%)
	Grain yield	Straw yield	Biological yield		
15 cm × 10 cm	5.26	7.45	12.71	0.71:1	41.37
15 cm × 15 cm	6.89	8.63	15.52	0.80:1	44.40
20 cm × 15 cm	5.84	7.67	13.52	0.76:1	43.22
20 cm × 20 cm	5.36	7.50	12.86	0.71:1	41.66
S. Em (±)	0.313	0.267	0.471	-	-
C.D. (P=0.05)	0.949	0.833	1.466	-	-

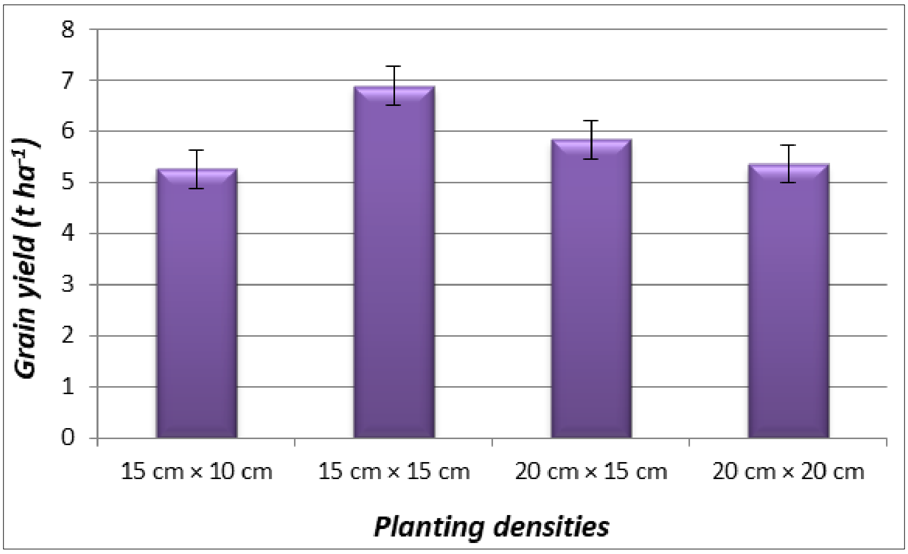

Fig 3: Effect of different planting densities on yield

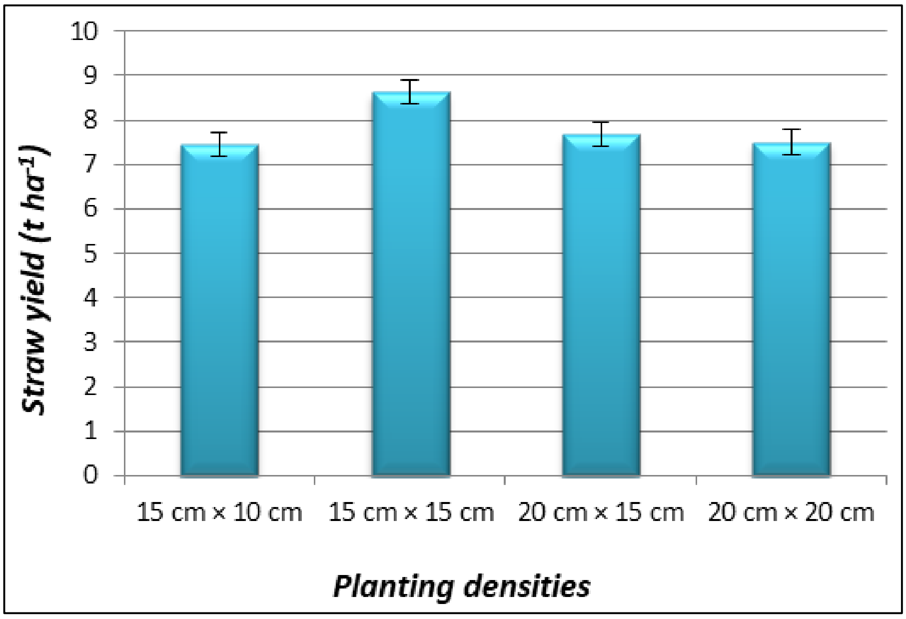

Fig 4: Effect of different planting densities on straw yield

Production economics

It was estimated that the maximum incurred in the treatment, rice transplanted at a spacing of 15 cm × 10 cm (Rs. 49825.00 ha^{-1}) and the minimum cost of cultivation was incurred in the treatment, rice transplanted at a spacing of 20 cm × 20 cm (Rs. 47681.00 ha^{-1}). Different treatment costs were responsible for this difference in total cost of cultivation between these two treatments (Table 4). The highest gross return was obtained from the treatment, rice transplanted at a spacing of 15 cm × 15 cm (Rs.120575.00 ha^{-1}) followed by the treatment, rice transplanted at a spacing of 20 cm × 15 cm (Rs. 102200.00 ha^{-1}). The lowest gross return (Rs. 81530.00 ha^{-1}) was obtained from the rice crop transplanted at a spacing of 15 cm × 10 cm. This was due to maximum rice yield obtained under the planting density of 15 cm × 15 cm. Report of Mahato *et al.* (2007) [13] supported this result. Similarly, the highest net return was obtained from the treatment, rice transplanted at a spacing of 15 cm × 15 cm (Rs. 71554.00 ha^{-1}). The lowest net return was obtained from the treatment, rice transplanted at a spacing of 15 cm × 10 cm (Rs. 31705.00 ha^{-1}). Mahato *et al.* (2007) [13] and Jena *et al.* (2010) [10] reported likewise. Highest input-output ratio was obtained from rice transplanted at a spacing of 15 cm × 15 cm (1:2.46) followed by rice transplanted at a spacing of 20 cm × 15 cm (1:2.12). The lowest input-output ratio was obtained from rice transplanting with the density of 15 cm × 10 cm (1:1.64). From these results, it was revealed that larger density of planting and lower density of planting than optimum planting density provided lower output with same level of input. Mahato *et al.* (2007) [13] and Jena *et al.* (2010) [10] reported similar findings previously. The data presented in Table 4 and Fig. 5 showed that the highest incremental cost-benefit ratio (ICBR) (1:1.46) was obtained from rice transplantation with the density of 15 cm × 15 cm which was followed by rice transplantation with the density of 20 cm × 15 cm (1:1.12). The lowest incremental cost-benefit ratio (ICBR) was obtained from rice transplanted at a spacing of 15 cm × 10 cm (1:0.64).

Table 4: Production economics of transplanted *kharif* rice cultivar CR Dhan 347 ((Maudamani)

Treatments (Planting densities)	Common cost (Rs. ha^{-1})	Treatment cost (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Input: output	ICBR
15 cm × 10 cm	42321	7504	49825	81530	31705	1:1.64	1:0.64
15 cm × 15 cm	42321	6700	49021	120575	71554	1:2.46	1:1.46
20 cm × 15 cm	42321	5896	48217	102200	53983	1:2.12	1:1.12
20 cm × 20 cm	42321	5360	47681	93800	46119	1:1.97	1:0.97

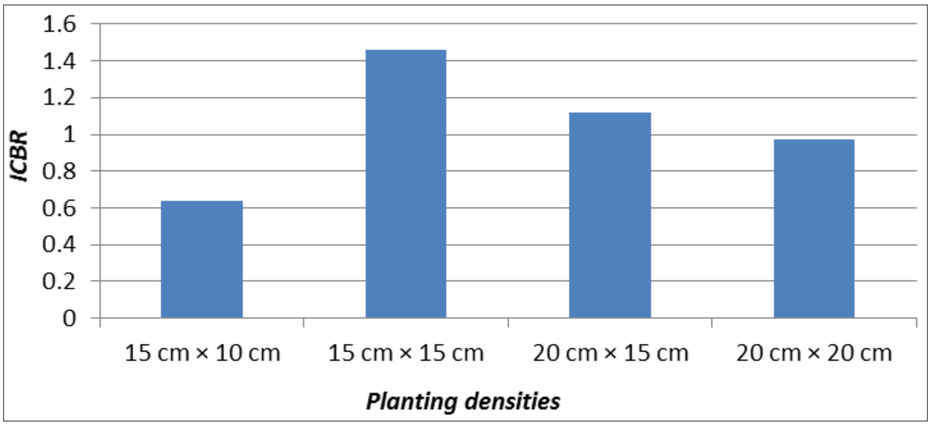

Fig 5: Effect of different planting densities on incremental cost-benefit ratio (ICBR)

Conclusion

The findings of our study depicted that 30 days old rice seedlings of high yielding cultivar 'CR Dhan 307 (Maudamani)' transplanted with a density of 15 cm × 15 cm could be the best for achieving better crop growth, higher grain yield and profit.

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