

PERFORMANCE OF RICE (*Oryza sativa* L.) CULTIVARS AT VARIOUS SPACINGS DURING *KHARIF* SEASON UNDER SOUTHERN ODISHA CONDITION

SUBIR RANA, TRIPTESH MONDAL, TANMOY SHANKAR and TUFLEUDDIN BISWAS

Department of Agronomy and Agroforestry, M. S. Swaminathan School of Agriculture,
Centurion University of Technology and Management,
Paralakhemundi, Gajapati -761 211 (Odisha), India

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ABSTRACT

A field experiment was conducted during *Kharif*, 2023 in split plot design with three replications. Results inferred that out of rice cultivars, V1-Naveen recorded highest plant height (113.3 cm), no. of tillers m^{-2} (292.1) and dry matter accumulation at harvest (1229.4 g m^{-2}). No. of panicles m^{-2} (207.7), length of panicle (25.7 cm), total no. of spikelets panicle $^{-1}$ (146.0), no. of filled grains panicle $^{-1}$ (125.6) and 1000-grain weight (21.4 g) than other two cultivars. Naveen recorded significantly higher grain yield (5.2 t ha^{-1}) than other cultivars due to the achievement of best results of all the yield attributing characters. The spacing of $15 \text{ cm} \times 15 \text{ cm}$ recorded the highest plant height at harvest (106.9 cm). Similarly, the significantly higher no. of tillers m^{-2} at 60 DAT (266.4) than other spacings due to lesser competition in utilization of available nutrients as compared to closer spacings and maximum dry matter accumulation at harvest (1094.2 g m^{-2}) were obtained with $15 \text{ cm} \times 15 \text{ cm}$ spacing. The maximum panicle length (23.1 cm), total no. of spikelets panicle $^{-1}$ (135.8), no. of filled grains panicle $^{-1}$ (120.7) and grain yield (4.7 t ha^{-1}) were recorded with $15 \text{ cm} \times 15 \text{ cm}$ spacing which were significantly higher than other spacing options. Highest panicle length (26.1 cm), number of filled grains panicle $^{-1}$ (128.7) and grain yield (5.5 t ha^{-1}) were recorded when Naveen cultivar was transplanted at $15 \text{ cm} \times 15 \text{ cm}$ spacing which was significantly higher than all other combinations.

Keywords: Cultivar, Spacing, Rice, Yield

INTRODUCTION

Rice (*Oryza sativa* L.) is the most widely consumed staple food for more than 60 per cent of the world's human population. Around 90 per cent of the world's rice production is being produced and eaten in Asia (Shankar *et al.*, 2021). India is the 2nd largest rice producing country in the world where rice

occupies 45.77 million hectares with a production of 124.37 million tonnes and productivity of 2.72 t ha^{-1} (Economics & statistics Division, DA&FW, GoI., 2021-22). Odisha is one of the leading rice-growing states in India and with an area of 3.84 million hectares, production of 9.52 million tonnes and productivity of 2.48 t ha^{-1} (Economics &

statistics Division, DA & FW, Gol., 2021-22). Rice is a high-calorie food, consisting of approximately 78.2% carbohydrates, 6.8% protein, 0.5% fat, and 0.6% minerals. Over the centuries, rice cultivation has spread across various regions of India, adapting to different climatic and geographical conditions. However, the full yield potential of rice cultivars is often limited by nutrient deficiencies and inadequate nutrient management practices. The selection of the appropriate cultivar, suited to the specific ecological conditions of a region, can be highly beneficial for farmers. Most of today's high-yielding rice cultivars are thermosensitive, meaning their growth periods and phenological phases are significantly influenced by the microenvironment.

Plant spacing determines the plant population in unit area thereby affecting the use efficiency of inputs and grain yield. Plant density is a major input which has a significant role in measuring growth and yield of the crop. Spacing of a crop influences the interception of solar radiation, plant canopy area, dry matter production and growth rate of a crop (Anwar *et al.*, 2011). The closer spacing results in competition among plants for light, water and nutrients which ultimately slows down the growth as well as the grain yield. Optimum plant spacing ensures proper growth of above-ground and underground portions by efficient utilization of solar radiation, nutrients and water resources. Similarly, the tillering habit and formation of spikelets panicle⁻¹ also affected by the spacing (Bithy *et al.*, 2020), which is responsible for the production of rice per unit area. So, the spacing should be optimized by keeping in mind the various aspects of crop management. Odisha is a predominantly agrarian state where rice is the staple crop, and introducing high-yielding, disease-resistant, and climate-resilient varieties has helped boost productivity and farmer livelihoods. Varieties such as Naveen, RNR 15048, and Satabdi

taken in the study are few among the major varieties growing in Odisha have been significant in terms of yield improvement, economic benefit, adaptability to local conditions, and sustainability. As spacing per unit area is an important management tool with reducing production cost and to get optimal grain yield from suitable rice cultivars, the present study has taken to understand how different spacings affect the growth, yield, and overall performance of major rice cultivars in Odisha.

MATERIAL AND METHODS

An experiment was carried out during *Kharif*, 2023 at M. S. Swaminathan School of Agriculture in Paralakhemundi, Gajapati district, Odisha. During the crop growing season, the weekly mean maximum and minimum temperatures ranged between 31.2° and 35.0°C and between 22.5° and 26.5°C, respectively. The crop received a total rainfall of 884.4 mm. The relative humidity varied from 83.6 to 89.7%. The bright sunshine hours ranged between 5.17 and 11.0 hours. The experimental soil was sandy loam in texture with a pH 6.2 and organic carbon content of 0.3%. Initial available nitrogen, phosphorus, potassium in the soil were 230 kg ha⁻¹, 12.7 kg ha⁻¹, 141.2 kg ha⁻¹, respectively. The experiment was laid out in a split plot design (SPD) with twelve treatment combinations. Main plot treatments were three different cultivars *viz.*, V₁- Naveen, V₂- RNR 15048, V₃- Satabdi and sub plot treatments were four different spacings *viz.*, S₁- 10 cm × 15 cm, S₂- 15 cm × 15 cm, S₃- 20 cm × 15 cm, S₄- 25 cm × 15 cm). Thirty-day old rice seedlings of all three cultivars were transplanted on 4th August, 2023. Two seedlings were transplanted in each hill of all the plots. According to the plan and arrangement, the field was divided into 36 plots, each of 4.8 m × 3 m *i.e.*, 14.4 m² area. Recommended dose of NPK @ 80 kg N, 40 kg

P₂O₅ and 40 kg K₂O ha⁻¹ were applied. The sources of fertilisers were urea, single superphosphate and muriate of potash. In all the treatments, entire recommended rates of phosphorus and potassium were applied as basal. N was applied in split doses. Half of N was applied at the time of sowing, and the remaining half of N was applied in two equal splits at tillering and panicle initiation.

Crop growth rate (CGR) was calculated at 30-60 DAT in the experiment. CGR is the gain in dry matter production by unit area of rice per unit time expressed as g m⁻² day⁻¹.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \text{ g m}^{-2} \text{ day}^{-1}$$

Where, W₁ = Dry weight of the above-ground plant parts per unit area at time t₁; W₂ = Dry weight of the above-ground plant parts per unit area at time t₂; t₁ = Time of 1st sampling and t₂ = Time of 2nd sampling

Relative growth rate (RGR) was also calculated at 30-60 DAT in the experiment. RGR represents as g of dry matter produced by g of existing dry matter per unit time and expressed as g g⁻¹ day⁻¹.

Where, W₁ = Dry weight of the above-ground plant parts per unit area at time t₁; W₂ = Dry weight of the above-ground plant parts per unit area at time t₂; t₁ = Time of 1st sampling and t₂ = Time of 2nd sampling

$$\frac{\log_e W_2 - \log_e W_1}{t_2 - t_1} \text{ g g}^{-1} \text{ day}^{-1}$$

Growing degree days (GDD) was calculated by using the following formula:

$$GDD (\text{! day hrs.}) = \sum_{T_{base}}^{T_{max.} + T_{min.}} (T_{max.} + T_{min.})/2 - T_{base}$$

Where, T_{max} = Daily maximum temperature (°C); T_{min} = Daily minimum temperature (°C); T_{base} = Base temperature of rice which was taken as 10°C; j is initial date of phenological phase of interest; k is last date

of phenological phase of interest and Σ is accumulated of starting to ending date of phenological phases.

Heliothermal units (HTU) was measured by using the following formula:

$$HTU (^\circ\text{C day hrs.}) = GDD \times \text{Bright sunshine hours}$$

Photothermal units (PTU) was calculated by using the following formula:

$$PTU (^\circ\text{C day hrs.}) = GDD \times \text{Day length}$$

Heat use efficiency (HUE) of rice was measured following Shamim *et al.* (2013), for which grain yield of the crop and the GDD from transplanting to physiological maturity were used.

$$HUE (\text{kg ha}^{-1} ^\circ\text{C day hrs.}^{-1}) = \text{Grain yield/GDD}$$

Heliothermal unit use efficiency (HTUE) of rice was measured by following the formula as per Sreenivas *et al.* (2010), for which grain yield of the crop and the HTU from transplanting to physiological maturity were used.

$$HTUE = \frac{\text{Grain yield}}{\text{HTU}} \times 100$$

To calculate the Coefficient of Variation (CV) for the yield attributes

Where:

S.Em. is the Standard Error of the Mean.

Mean is the average value for each yield attribute across the cultivars.

RESULTS AND DISCUSSION

Growth parameters

The findings (Table 1) showed that the rice cultivar, Naveen expressed significant superiority in the growth parameters *viz.*, plant height at harvest (113.3 cm) (Figure 1A),

number of tillers m^{-2} at 60 DAT (292.1), dry matter accumulation (DMA) at harvest (1229.4 g m^{-2}) and crop growth rate (CGR) at 30-60 DAT ($11.8 \text{ g m}^{-2} \text{ day}^{-1}$) in comparison to the other cultivars. The lowest plant height at harvest (98.1 cm), number of tillers m^{-2} at 60 DAT (238.3) and DMA at harvest (961.8 g m^{-2}) were obtained with the cultivar, Satabdi which was significantly lower than other two cultivars. The minimum CGR was recorded with RNR 15048 ($9.4 \text{ g m}^{-2} \text{ day}^{-1}$) which was significantly lower than Naveen and Satabdi. The leaf area index (LAI) at 60 DAT was significantly higher in RNR 15048 (2.5) cultivar than others (Figure 2A) and it was significantly lower in

Naveen (2.3) cultivar than others. But the cultivar, Satabdi showed significant superiority in RGR at 30-60 DAT ($0.0186 \text{ g g}^{-1} \text{ day}^{-1}$). RGR at 30-60 DAT was found same in the cultivar, Naveen ($0.0149 \text{ g g}^{-1} \text{ day}^{-1}$) and RNR 15048 ($0.0149 \text{ g g}^{-1} \text{ day}^{-1}$). The maximum DMA under the cultivar, Naveen was probably due to better nutrient utilization efficiency of this cultivar than two other cultivars used in the experiment.

Among the different spacings (Table 1), $15 \text{ cm} \times 15 \text{ cm}$ showed significantly higher results of growth parameters *i.e.*, plant height at harvest (106.9 cm) (Figure 1B), number of tillers m^{-2} at 60 DAT (266.4) and LAI at 60 DAT

Table 1: Growth parameters of rice as influenced by the cultivars under different spacings

Treatments	Growth parameters					
	Plant height (cm) at harvest	No. of tillers m^{-2} at 60 DAT	DMA (g m^{-2}) at harvest	LAI at 60 DAT	CGR at 30-60 DAT ($\text{g m}^{-2} \text{ day}^{-1}$)	RGR at 30-60 DAT ($\text{g g}^{-1} \text{ day}^{-1}$)
Mainplot treatments: Cultivars						
V ₁ : Naveen	113.3	292.1	1229.4	2.3	11.8	0.0149
V ₂ : RNR 15048	104.0	255.9	1011.2	2.5	9.4	0.0149
V ₃ : Satabdi	98.1	238.3	961.8	2.5	10.6	0.0186
S. Em. ($\pm$)	0.71	1.26	13.08	0.010	0.13	0.0004
C.D. (P=0.05)	2.13	3.79	45.80	0.034	0.45	0.0015
CV (%)	2.34	1.67	4.25	1.45	4.35	8.16
Subplot treatments: Spacings						
S ₁ : $10 \text{ cm} \times 15 \text{ cm}$	103.6	257.4	1044.1	2.4	10.3	0.0163
S ₂ : $15 \text{ cm} \times 15 \text{ cm}$	106.9	266.4	1094.2	2.5	10.6	0.0157
S ₃ : $20 \text{ cm} \times 15 \text{ cm}$	105.7	264.0	1073.2	2.4	10.7	0.0161
S ₄ : $25 \text{ cm} \times 15 \text{ cm}$	104.2	260.4	1058.3	2.4	10.7	0.0165
S.Em. ($\pm$)	0.38	0.73	9.87	0.004	0.06	0.0001
C.D. (P=0.05)	1.14	2.18	29.65	0.014	0.18	0.0003
CV (%)	1.08	0.84	2.77	0.47	1.69	1.36
Cultivar $\times$ Spacing						
S.Em. ($\pm$)	0.65	1.27	17.09	0.007	0.10	0.0001
C.D. (P=0.05)	1.95	NS	NS	0.024	0.31	0.0004

Table 1A. Interaction effect between cultivars and spacings on plant height (cm) at harvest

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V ₁ : Naveen	V ₂ : RNR 15048	V ₃ : Satabdi	Mean
S ₁ : 10 cm × 15 cm	112.3	101.7	96.9	103.6
S ₂ : 15 cm × 15 cm	114.2	108.0	98.5	106.9
S ₃ : 20 cm × 15 cm	113.8	104.5	98.9	105.7
S ₄ : 25 cm × 15 cm	112.8	101.9	97.9	104.2
Mean	113.3	104.0	98.1	
S.Em. (±)		0.65		
C.D. (P=0.05)		1.95		

(2.5) in comparison to the other plant spacing treatments though this spacing showed significantly lower RGR at 30-60 DAT (0.0157 g g⁻¹ day⁻¹) than all other options. The spacing of 15 cm × 15 cm (1094.2 g m⁻²) recorded highest DMA at harvest which was statistically *at par* with the spacing of 20 cm × 15 cm (1073.2 g m⁻²). In case of CGR at 30-60 DAT, 15 cm × 15 cm spacing (10.6 g m⁻² day⁻¹) recorded statistically *at par* result with 25 cm × 15 cm spacing (10.7 g m⁻² day⁻¹) and 20 cm × 15 cm spacing (10.7 g m⁻² day⁻¹) but significantly higher result than 10 cm × 15 cm spacing (10.3 g m⁻² day⁻¹). The shortest plants at harvest (103.6 cm), number of tillers m⁻² at

60 DAT (257.4) and LAI at 60 DAT (2.4) (Figure 2B) were obtained with planting distance of 10 cm × 15 cm.

The number of tillers m⁻² was decreased with the closer spacing because of competition in utilization of available nutrients as compared to wider spacing where more interception of solar radiation and lesser inter-plant competition prevailed as reported by Mohammad *et al.* (2004). LAI was found lower in closer spacing due to limitation of sunlight due to mutual shading effect among the leaves in densely populated plants (Mondal and Puteh, 2013).

Table 1B: Interaction effect between cultivars and spacings on LAI at 60 DAT

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V ₁ : Naveen	V ₂ : RNR 15048	V ₃ : Satabdi	Mean
S ₁ : 10 cm × 15 cm	2.3	2.5	2.4	2.4
S ₂ : 15 cm × 15 cm	2.4	2.6	2.5	2.5
S ₃ : 20 cm × 15 cm	2.3	2.5	2.5	2.4
S ₄ : 25 cm × 15 cm	2.3	2.5	2.5	2.4
Mean	2.3	2.5	2.5	
S.Em. (±)		0.007		
C.D. (P=0.05)		0.02		

Table 1C. Interaction effect between cultivars and spacings on CGR at 30-60 DAT ($\text{g m}^{-2} \text{d}^{-1}$)

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V_1 : Naveen	V_2 : RNR 15048	V_3 : Satabdi	Mean
S_1 : 10 cm $\times$ 15 cm	11.0	9.9	10.1	10.3
S_2 : 15 cm $\times$ 15 cm	12.3	9.0	10.5	10.6
S_3 : 20 cm $\times$ 15 cm	12.1	9.3	10.7	10.7
S_4 : 25 cm $\times$ 15 cm	11.8	9.4	11.0	10.7
Mean	11.8	9.4	10.6	
S.Em. ($\pm$)		0.10		
C.D. (P=0.05)		0.31		

In case of interaction (Table 1A and Table 1C), highest plant height at harvest (114.2 cm) and CGR at 30-60 DAT ($12.3 \text{ g m}^{-2} \text{ day}^{-1}$) were obtained under the combination of the cultivar, Naveen and planting distance of 15 cm $\times$ 15 cm which were statistically *at par* with the treatment combination of the cultivar, Naveen and planting distance of 20 cm $\times$ 15 cm where 113.8 cm and $12.1 \text{ g m}^{-2} \text{ day}^{-1}$ were plant height at harvest and CGR at 30-60 DAT, respectively. But LAI at 60 DAT was found highest under the combination of the cultivar, RNR 15048 and planting distance of

15 cm $\times$ 15 cm (2.6) which was significantly higher than all other treatment combinations (Table 1B). Maximum RGR at 30-60 DAT was obtained (Table 1D) under the combination of the cultivar, Satabdi and plant spacing of 25 cm $\times$ 15 cm ($0.0187 \text{ g g}^{-1} \text{ day}^{-1}$) which was significantly higher than all other treatment combinations.

Phenological dates

The cultivar, RNR 15048 took significantly more no. of days to attain 50% flowering (60.3 DAT) and physiological maturity (82.0 DAT)

Table 1D. Interaction effect between cultivars and spacings on RGR at 30-60 DAT ($\text{g g}^{-1} \text{d}^{-1}$)

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V_1 : Naveen	V_2 : RNR 15048	V_3 : Satabdi	Mean
S_1 : 10 cm $\times$ 15 cm	0.0148	0.0149	0.0193	0.0163
S_2 : 15 cm $\times$ 15 cm	0.0152	0.0140	0.0180	0.0157
S_3 : 20 cm $\times$ 15 cm	0.0151	0.0146	0.0187	0.0161
S_4 : 25 cm $\times$ 15 cm	0.0146	0.0161	0.0187	0.0165
Mean	0.0149	0.0149	0.0186	
S.Em. ($\pm$)		0.0001		
C.D. (P=0.05)		0.0004		

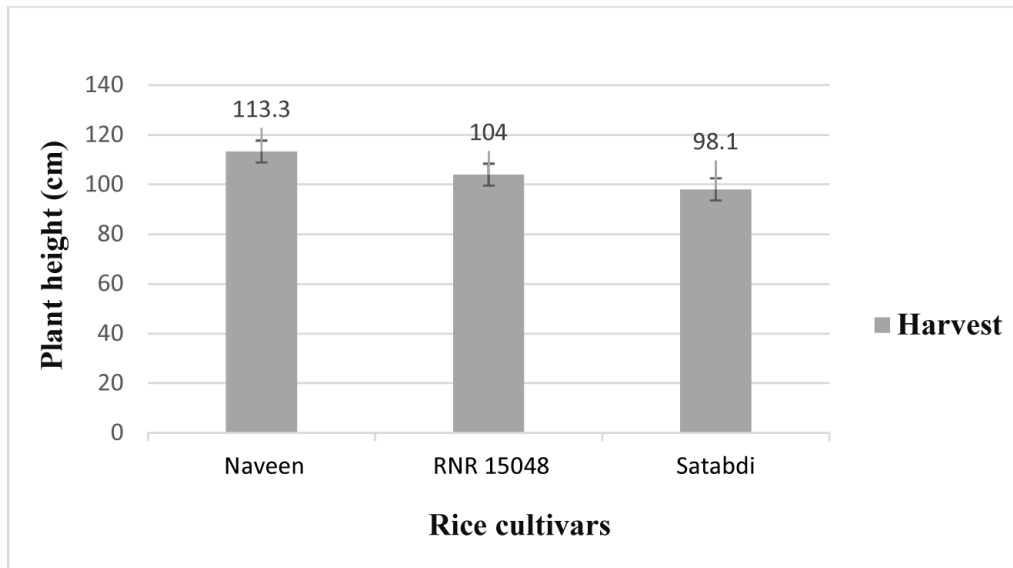


Figure 1A. Plant height at harvest (cm) as influenced by the cultivars

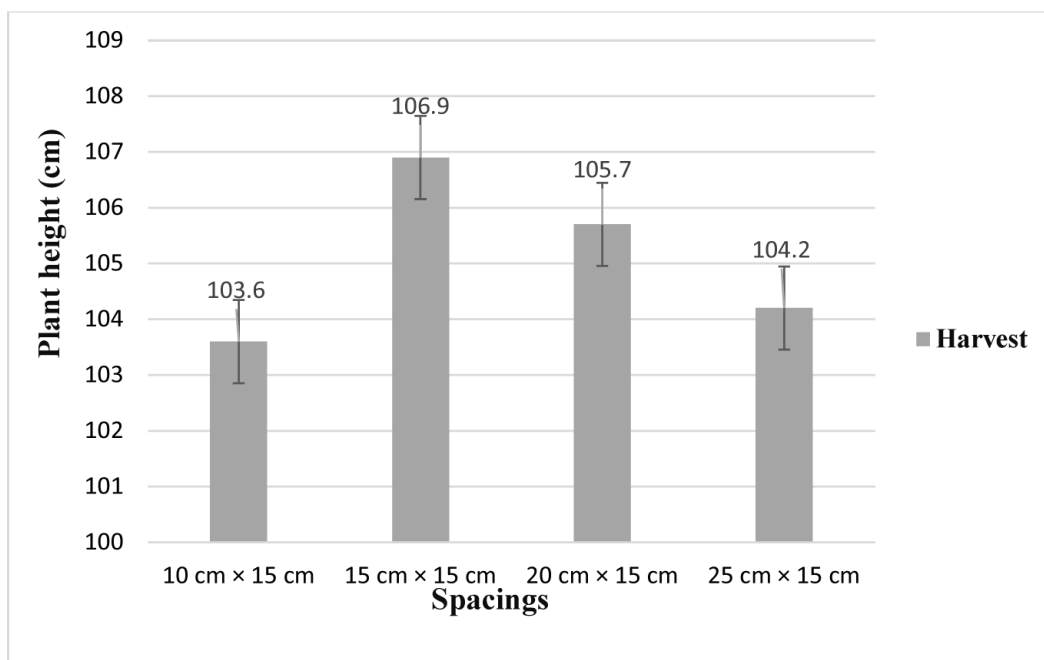


Figure 1B. Plant height at harvest (cm) as influenced by the different spacings

than other two rice cultivars due to its longer growing period *i.e.*, 120-125 days (Figure 3A and Figure 3B). For attaining 50% flowering and physiological maturity, the cultivar, Naveen (56.6 and 78.9 DAT, respectively) which was a cultivar of 115-120 days duration (Patnaik *et al.*, 2008) took statistically similar time period with the cultivar, Satabdi (55.6 and 78.3 DAT,

respectively) which was also a cultivar of 120 days duration (ICAR-NRRI, 2000).

Days to 50% flowering was significantly influenced by the different planting spaces and 25 cm × 15 cm of spacing *i.e.*, 26 hills m⁻² took highest no. of days to attain 50% flowering (58.1 DAT). The no. of days required to attain 50% flowering with the spacing of 15 cm × 15

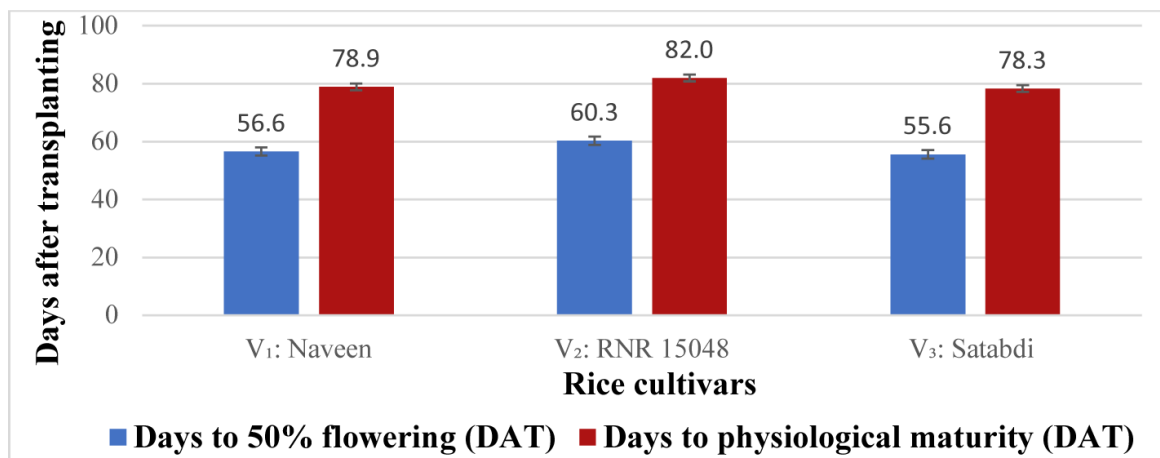


Figure 3A. Days to 50% flowering and days to physiological maturity as influenced by the cultivars

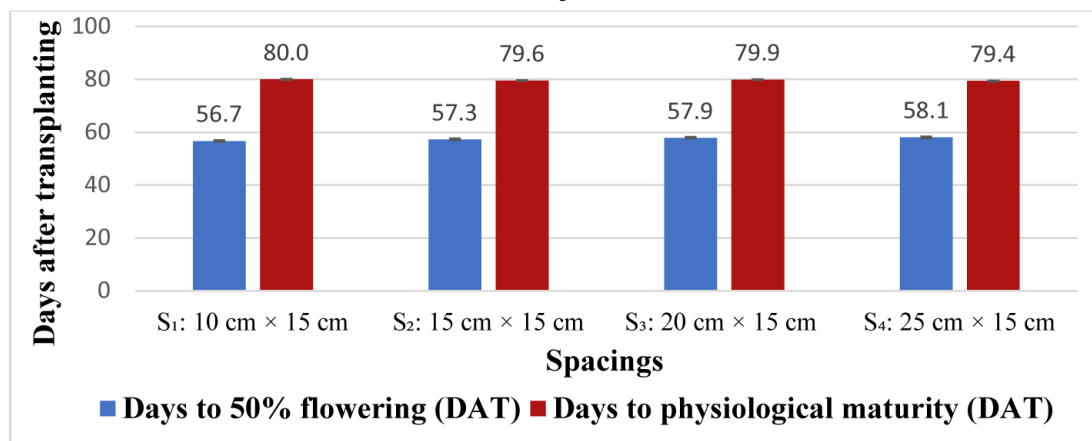


Figure 3B. Days to 50% flowering and days to physiological maturity as influenced by the different spacings

cm *i.e.*, 44 hills m⁻² (57.3 DAT) and 10 cm × 15 cm *i.e.*, 66 hills m⁻² (56.6 DAT) were significantly lesser than the earlier one due to less water stress per plant resulted in less elongation of stems and leaves (Nishiuchi *et al.*, 2012) which leads to shorter vegetative phase of rice plants under these two plant spacings than the previously mentioned plant spacing. The spacing of 20 cm × 15 cm *i.e.*, 33 hills m⁻² (57.9 DAT) taken statistically similar time duration with the spacing of 25 cm × 15 cm for attaining 50% flowering. This result indicated that the similar CGR at 30-60 DAT under these two spacings leads to attain 50% flowering in statistically similar time. The different spacings

had no significant impact in the attainment of physiological maturity of rice plants.

Yield attributes

Different rice cultivars had a substantial impact on yield attributes such as the no. of panicles m⁻², length of panicle, total no. of spikelets panicle⁻¹, no. of filled grains panicle⁻¹ and 1000-grain weight (Table 2). It was observed that the cultivar, Naveen had significantly higher results of all the yield attributing characters (207.7, 25.5 cm, 146.0, 125.6 and 21.4 g were number of panicles m⁻², length of panicle, total number of spikelets panicle⁻¹, number of filled grains panicle⁻¹ and 1000-grain weight, respectively) than all other

cultivars. Significantly higher no. of panicles m^{-2} , panicle length and 1000-grain weight were previously found under the rice cultivar, Naveen than other cultivars (Satapathy *et al.*, 2016). This was mainly due to significantly higher CGR at 30-60 DAT of the rice cultivar, Naveen than others. The minimum panicle length (20.6 cm), total no. of spikelets panicle⁻¹ (120.6), no. of filled grains panicle⁻¹ (110.5) and 1000-grain weight (18.1 g) were found with the cultivar, Satabdi. But the cultivar, RNR 15048 recorded significantly lower no. of panicles m^{-2} (179.0) than Naveen and Satabdi. Number of panicles m^{-2} were higher in the cultivar, Naveen and Satabdi was mainly due to more CGR at 30-60 DAT than RNR 15048. The higher no. of panicles⁻² in the rice cultivar, Satabdi than RNR 15048 was also due to more RGR at 30-60 DAT which was in agreement with the previous report of Gill *et al.* (2006).

It was also observed that the yield attributing characters were significantly increased under 15 cm $\times$ 15 cm of spacing (23.1 cm, 135.8, 120.7 and 21.4 g were length of panicle, total no. of spikelets panicle⁻¹ and no. of filled grains panicle⁻¹, respectively) than all other spacings except number of panicles m^{-2} (197.3) and 1000-grain weight (20.0 g) which were statistically *at par* with the spacing of 20 cm $\times$ 15 cm (194.1 and 20.0 g were number of panicles m^{-2} and 1000-grain weight, respectively) (Table 2). But it was not happened under the spacing of 20 cm $\times$ 15 cm which indicated the optimum availability of all resources under 15 cm $\times$ 15 cm spacing resulted in maximum no. of panicles m^{-2} . 1000-grain weight being a genetic character was not significantly varied by minor variation in row to row spacing. Similarly, spacing of 10 cm $\times$ 15 cm (188.1) provided significantly lower no. of panicles m^{-2} than all other spacings. The closer spacing reduced the no. of effective tillers m^{-2} and increased tiller mortality due to scarcity of light, water and nutrient. Hence, lower no. of

panicles m^{-2} was obtained (Patra and Nayak, 2001). The minimum panicle length (21.4 cm) and total no. of spikelets panicle⁻¹ (130.9) were recorded with the spacing of 10 cm $\times$ 15 cm. Poor utilization of growth resources, more intra species competition coupled with lower availability of nutrients among the narrowly spaced crop plants may be ascribed the reason for inferiority in panicle length and total number of spikelets panicle⁻¹ of rice (Rasool *et al.*, 2012). The minimum no. of filled grains panicle⁻¹ was obtained with the spacing, 10 cm $\times$ 15 cm (115.3) which was statistically *at par* with the spacing, 25 cm $\times$ 15 cm (116.0). This was due to the fact that no. of filled grain panicle⁻¹ is determined by the rate of spikelet differentiation (Li *et al.*, 2021) which was ultimately depended on RGR at 30-60 DAT.

Interaction between cultivar and spacing showed significant response towards number of panicles m^{-2} (Table 2A), panicle length (Table 2B) and number of filled grains panicle⁻¹ (Table 2C). Longest panicle (26.1 cm) and maximum no. of filled grains panicle⁻¹ (128.7) were obtained with the combination of the cultivar, Naveen and spacing of 15 cm $\times$ 15 cm which was significantly higher than all other treatments combinations. But the number of panicles m^{-2} under the cultivar, Naveen at spacing of 15 cm $\times$ 15 cm (213.0) was statistically *at par* with the cultivar, Naveen with the spacing of 20 cm $\times$ 15 cm (210.7).

Yield and harvest index

Grain yield of rice was significantly higher in the cultivar, Naveen (5.2 t ha^{-1}) than other two cultivars (Table 3). This was due to the achievement of best results of all the yield attributing characters in Naveen. The minimum grain yield was achieved in the cultivar, Satabdi (3.8 t ha^{-1}) which showed the least results of all the yield attributes except no. of panicles m^{-2} . Straw yield was also recorded significantly higher in the cultivar, Naveen (9.2 t ha^{-1}) than

Table 2. Yield attributes of rice as influenced by the cultivars combined with different spacings

Treatments	Yield attributes				
	No. of panicles m ⁻²	Panicle length (cm)	Total No. of spikelets panicle ⁻¹	No. of filled grains panicle ⁻¹	1000 -grain weight (g)
Mainplot treatments: Cultivars					
V ₁ : Naveen	207.7	25.5	146.0	125.6	21.4
V ₂ : RNR 15048	179.0	21.5	133.7	116.1	20.3
V ₃ : Satabdi	189.8	20.3	120.6	110.5	18.1
S.Em. (±)	2.08	0.09	0.81	1.30	0.02
C.D. (P=0.05)	7.28	0.32	2.83	4.55	0.07
CV (%)	3.75	1.42	2.09	3.84	0.37
Subplot treatments: Spacings					
S ₁ : 10 cm × 15 cm	188.1	21.4	130.9	115.3	19.9
S ₂ : 15 cm × 15 cm	197.3	23.1	135.8	120.7	20.0
S ₃ : 20 cm × 15 cm	194.1	22.8	134.4	117.6	20.0
S ₄ : 25 cm × 15 cm	189.1	22.4	132.6	116.0	19.9
S.Em. (±)	0.98	0.03	0.20	0.27	0.01
C.D. (P=0.05)	3.43	0.10	0.59	0.80	0.03
CV (%)	1.53	0.42	0.44	0.69	0.16
Cultivar × Spacing					
S.Em. (±)	1.70	0.05	0.34	0.46	0.02
C.D. (P=0.05)	5.05	0.16	NS	1.38	NS

Table 2A: Interaction effect between cultivars and spacings on number of panicles m⁻²

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V ₁ : Naveen	V ₂ : RNR 15048	V ₃ : Satabdi	Mean
S ₁ : 10 cm × 15 cm	200.0	178.3	186.0	188.1
S ₂ : 15 cm × 15 cm	213.0	184.3	194.7	197.3
S ₃ : 20 cm × 15 cm	210.7	181.0	190.7	194.1
S ₄ : 25 cm × 15 cm	207.0	172.3	188.0	189.1
Mean	207.7	179.0	189.8	
S.Em. (±)		1.70		
C.D. (P=0.05)		5.05		

Table 2B: Interaction effect between cultivars and spacings on panicle length (cm)

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V ₂ : Naveen	V ₂ : RNR 15048	V ₃ : Satabdi	Mean
S ₁ : 10 cm × 15 cm	24.6	20.3	19.4	21.4
S ₂ : 15 cm × 15 cm	26.1	22.1	21.0	23.1
S ₃ : 20 cm × 15 cm	25.8	21.8	20.7	22.8
S ₄ : 25 cm × 15 cm	25.3	21.3	20.4	22.4
Mean	25.5	21.5	20.3	
S.Em. (±)		0.05		
C.D. (P=0.05)		0.16		

Table 2C. Interaction effect between cultivars and spacings on number of filled grains panicle⁻¹

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V ₁ : Naveen	V ₂ : RNR 15048	V ₃ : Satabdi	Mean
S ₁ : 10 cm × 15 cm	122.7	115.3	108.0	115.3
S ₂ : 15 cm × 15 cm	128.7	119.3	114.0	120.7
S ₃ : 20 cm × 15 cm	126.3	117.0	109.3	117.6
S ₄ : 25 cm × 15 cm	124.7	112.7	110.7	116.0
Mean	125.6	116.1	110.5	
S.Em. (±)		0.46		
C.D. (P=0.05)		1.38		

all others. The minimum straw yield was obtained in the cultivar, RNR 15048 (7.4 t ha⁻¹) which was statistically *at par* with the cultivar, Satabdi (7.7 t ha⁻¹) (Table 3). Harvest index of rice was varied significantly due to the various cultivars used in this experiment (Table 3). The cultivar, RNR 15048 recorded highest harvest index (36.4%) which was statistically *at par* with the cultivar, Naveen (35.9%). The cultivar, Satabdi recorded significantly lower harvest index (33.1%) than other two cultivars. This might be due to lower translocation of

photosynthates from vegetative part to sink in case of the cultivar, Satabdi.

Spacing, 15 cm × 15 cm provided significantly higher grain yield (4.7 t ha⁻¹) than all other spacings. The higher grain yield with closer spacing was owing to significantly higher no. of panicles m⁻² (Patra and Nayak, 2001), longer panicle length, more no. of spikelets panicle⁻¹, more no. of filled grains panicle⁻¹ and higher 1000-grain weight. Bashir *et al.* (2010) and also reported significant positive correlation between grain yield and panicle

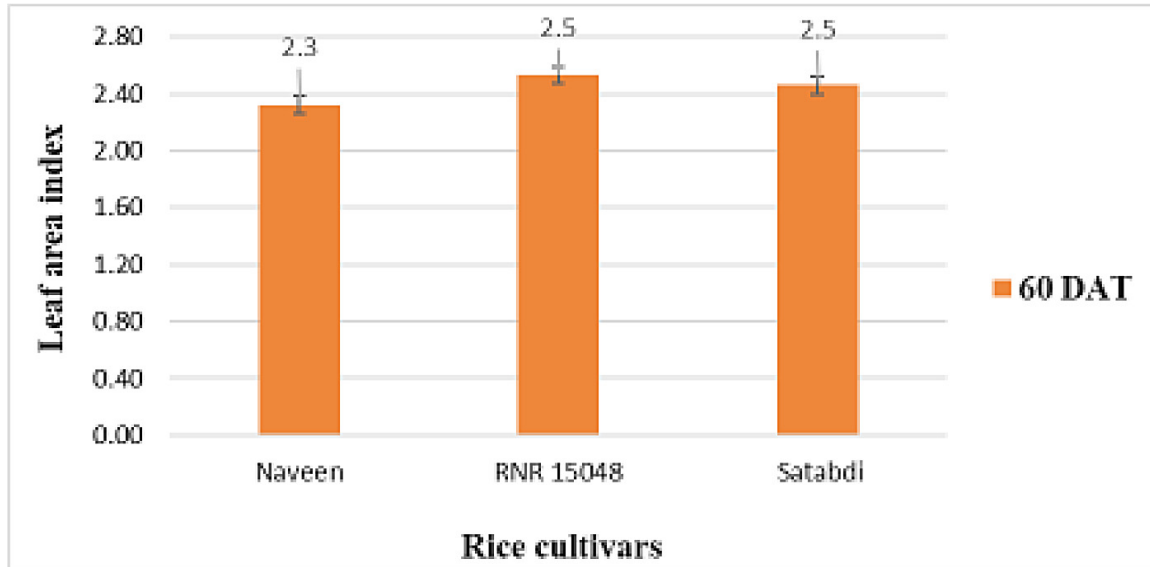


Figure 2A. Leaf area index (LAI) at 60 DAS as influenced by the cultivars

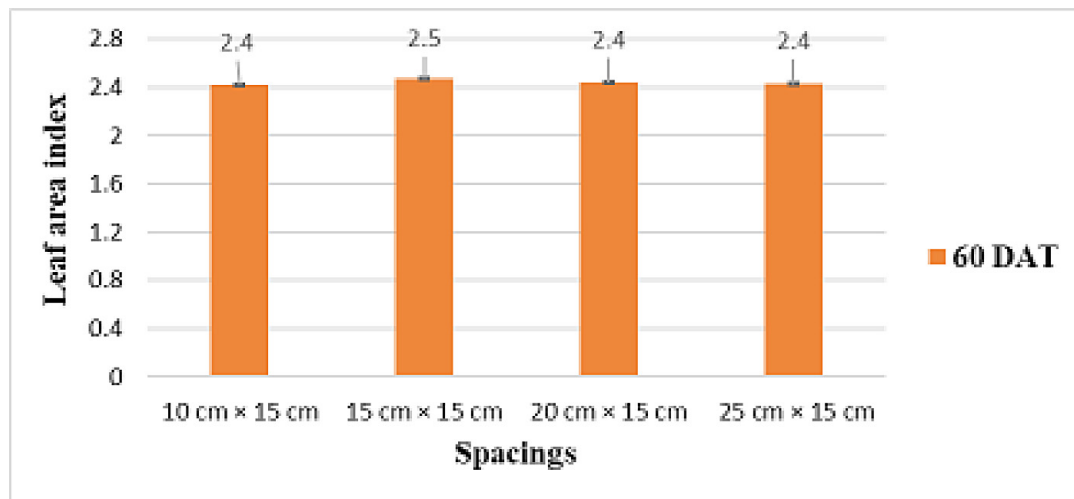


Figure 2B. Leaf area index (LAI) at 60 DAS as influenced by the different spacings

length; grain yield and number of panicles m^{-2} , respectively. The minimum grain yield was found with the plant spacing, 25 cm × 15 cm (4.3 t ha^{-1}) which was statistically *at par* with the plant spacing of 10 cm × 15 cm (4.2 t ha^{-1}). In case of plant spacing, 15 cm × 15 cm recorded significantly higher straw yield (8.4 t ha^{-1}) than 10 cm × 15 cm (7.9 t ha^{-1}) and 25 cm × 15 cm (8.0 t ha^{-1}) but it was statistically *at par* with 20 cm × 15 cm (8.2 t ha^{-1}). The plant spacing of 10 cm × 15 cm and 25 cm × 15 cm recorded statistically *at par* result in respect to

straw yield. The harvest index was recorded maximum with the spacing of 15 cm × 15 cm (36.0%) which was statistically *at par* with the spacing of 20 cm × 15 cm (35.3%). The lowest harvest index was recorded with the spacing, 10 cm × 15 cm (34.1%) which was statistically *at par* with the spacing of 25 cm × 15 cm (34.6%). These results were related to achievement of similar straw yield under both the spacing options.

Table 3. Yield and harvest index of rice as influenced by the cultivars combined with different spacings

Treatments	Yield		
	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Harvest index (%)
Mainplot treatments: Cultivars			
V ₁ : Naveen	5.2	9.2	35.9
V ₂ : RNR 15048	4.2	7.4	36.4
V ₃ : Satabdi	3.8	7.7	33.1
S.E.m. (±)	0.04	0.11	0.38
C.D. (P=0.05)	0.13	0.35	1.19
Subplot treatments: Spacings			
S ₁ : 10 cm × 15 cm	4.2	7.9	34.1
S ₂ : 15 cm × 15 cm	4.7	8.4	36.0
S ₃ : 20 cm × 15 cm	4.5	8.2	35.3
S ₄ : 25 cm × 15 cm	4.3	8.0	34.6
S.E.m. (±)	0.01	0.09	0.26
C.D. (P=0.05)	0.03	0.28	0.78
Cultivar × Spacing			
S.E.m. (±)	0.02	0.16	0.45
C.D. (P=0.05)	0.06	NS	NS

Table 3A: Interaction effect between cultivars and spacings on grain yield (t ha⁻¹)

Subplot treatments: Spacings	Mainplot treatments: Cultivars			
	V ₁ : Naveen	V ₂ : RNR 15048	V ₃ : Satabdi	Mean
S ₁ : 10 cm × 15 cm	4.8	4.1	3.6	4.2
S ₂ : 15 cm × 15 cm	5.5	4.5	4.1	4.7
S ₃ : 20 cm × 15 cm	5.3	4.3	3.9	4.5
S ₄ : 25 cm × 15 cm	5.0	4.0	3.8	4.3
Mean	5.2	4.2	3.8	
S.E.m. (±)		0.02		
C.D. (P=0.05)		0.06		

Grain yield was significantly varied due to the interaction between the cultivars and spacings where Naveen combined with 15 cm × 15 cm of spacing showed significantly higher grain yield than all other treatment combinations (5.5 t ha⁻¹) (Table 3A).

Agrometeorological indices, heat use efficiency (HUE) and heliothermal unit use efficiency (HTUE)

The Maximum GDD, HTU and PTU were accumulated (1140.3, 10560.6, 14148.3 °C day hours were GDD, HTU and PTU, respectively) in the phenophase, transplanting to 50% flowering when the cultivar, RNR 15048 was transplanted with the spacing of 20 cm × 15 cm and 25 cm × 15 cm (Table 4). This finding was obtained because of more thermal energy accumulation as a result of longer vegetative period of RNR 15048 and longer period of this phenophase under wider row spacing. The highest GDD, HTU and PTU accumulated by the cultivar, Satabdi and the plant spacing of 10 cm × 15 cm (435.6, 4062.2, 5080.0 ! day hours were GDD, HTU and PTU, respectively) in the phenological phase, 50% flowering to physiological maturity. This finding supported the fact that Satabdi accumulated maximum thermal energy when transplanted in closer spacing during 50% flowering to physiological maturity as a result of delay in attainment of physiological maturity with closer plant spacing. Senescence of leaves and slower nutrient acquisition rate of plant roots in the post anthesis period resulted in more leaching and volatilization loss as well as lower uptake major nutrients in widely spaced crop which led to earlier attainment of physiological maturity than densely planted crop. On the other hand, Satabdi had slightly longer duration of the phenophase, 50% flowering to physiological maturity than two other cultivars.

The Maximum heat use efficiency (HUE) and heliothermal unit use efficiency (HTUE)

were recorded by the cultivar, Naveen under the spacing of 15 cm × 15 cm (0.00377 and 0.00040 kg ha⁻¹ °C day hrs.⁻¹ were HUE and HTUE, respectively) (Table 4). This was due to achievement of maximum grain yield of the cultivar, Naveen when transplanted at 15 cm × 15 cm spacing. The efficiencies were recorded minimum for the cultivar, Satabdi under the spacing of 10 cm × 15 cm (0.00247 and 0.00026 kg ha⁻¹ °C day hrs.⁻¹ were HUE and HTUE, respectively). This was due to the minimum grain yield of Satabdi when transplanted at 10 cm × 15 cm spacing.

Economics

The cultivation cost of the cultivar, Satabdi was minimum (₹ 45086 ha⁻¹) due to lower market price of seeds than other two cultivars. The planting distance of 25 cm × 15 cm showed minimum cost of cultivation (42776 ha⁻¹) due to requirement of lesser no. of seedlings per unit area than all other planting distances. Cost of cultivation was also minimum when the cultivar, Satabdi was transplanted at 25 cm × 15 cm spacing i.e., V₃S₄ (42745 ha⁻¹) (Table 5). Gross return (114253 ha⁻¹) and net return (68848 ha⁻¹) were found highest when Naveen was cultivated. The probable reason behind this result was Naveen provided higher grain yield than others. Similarly, the plant spacing of 15 cm × 15 cm achieved maximum gross return and net return due to maximum grain yield under this plant spacing option. In case of interaction effect, the cultivar, Naveen when transplanted at the spacing of 15 cm × 15 cm i.e., V₁S₁ maximum gross and net profit was observed due to achievement of maximum grain yield. In case of benefit-cost (B:C) ratio, the cultivar, Naveen showed best result due maximum proportionate increase in net return with respect to cost of cultivation. The spacing of 15 cm × 15 cm noted highest B:C ratio. Higher proportionate increase in net return with respect to cost of

Table 4. GDD, HTU and PTU at transplanting–50% flowering and 50% flowering–physiological maturity accumulated by the cultivars under different spacings and HUE and HTUE of the cultivars under different spacings

	Transplanting–50% flowering			50% flowering–physiological maturity			HUE (kg ha ⁻¹ °C day hrs. ⁻¹)	HTUE (kg ha ⁻¹ °C day hrs. ⁻¹)
	GDD (°C day hours)	HTU (°C day hours)	PTU (°C day hours)	GDD (°C day hours)	HTU (°C day hours)	PTU (°C day hours)		
Cultivar- Naveen								
10 cm × 15 cm	1041.8	9723.0	12983.9	433.8	4038.6	5049.2	0.00325	0.00035
15 cm × 15 cm	1041.8	9723.0	12983.9	415.7	3867.2	4843.3	0.00377	0.00040
20 cm × 15 cm	1062.2	9891.9	13225.5	432.1	4015.2	5020.0	0.00355	0.00038
25 cm × 15 cm	1062.2	9891.9	13225.5	395.4	3698.3	4601.7	0.00343	0.00037
Cultivar- RNR 15048								
10 cm × 15 cm	1102.6	10215.2	13703.7	426.6	4019.6	4938.6	0.00268	0.00029
15 cm × 15 cm	1122.0	10400.0	13933.3	407.2	3834.8	4709.0	0.00294	0.00032
20 cm × 15 cm	1140.3	10560.6	14148.3	388.9	3674.2	4494.0	0.00281	0.00030
25 cm × 15 cm	1140.3	10560.6	14148.3	388.9	3674.2	4494.0	0.00262	0.00028
Cultivar- Satabdi								
10 cm × 15 cm	1021.9	9528.0	12747.2	435.6	4062.2	5080.0	0.00247	0.00026
15 cm × 15 cm	1041.8	9723.0	12983.9	415.7	3867.2	4843.3	0.00281	0.00030
20 cm × 15 cm	1041.8	9723.0	12983.9	415.7	3867.2	4843.3	0.00268	0.00029
25 cm × 15 cm	1062.2	9891.9	13225.5	395.4	3698.3	4601.7	0.00261	0.00028

*GDD: Growing degree days; PTU: Photothermal units; HTU: Heliothermal units; HUE: heat use efficiency; HTUE: heliothermal unit use efficiency

Table 5. Economics of rice as influenced by the cultivars planted in different spacings

Treatments	Cost of cultivation (₹ ha ⁻¹)	Gross return (₹ ha ⁻¹)	Net return (₹ ha ⁻¹)	B:C ratio
Mainplot treatments: Cultivars				
V ₁ : Naveen	45160	112798	67638	1.5
V ₂ : RNR 15048	45159	97485	52327	1.2
V ₃ : Satabdi	45086	80369	35284	0.8
Subplot treatments: Spacings				
S ₁ : 10 cm × 15 cm	48633	91846	43214	0.9
S ₂ : 15 cm × 15 cm	45379	103344	57965	1.3
S ₃ : 20 cm × 15 cm	43752	98464	54712	1.3
S ₄ : 25 cm × 15 cm	42776	93883	51107	1.2
Cultivar × Spacing				
V ₁ S ₁	48672	105923	57252	1.2
V ₁ S ₂	45405	120253	74848	1.7
V ₁ S ₃	43772	115390	71618	1.6
V ₁ S ₄	42792	109627	66835	1.6
V ₂ S ₁	48670	94733	46063	1.0
V ₂ S ₂	45404	103698	58295	1.3
V ₂ S ₃	43771	98779	55008	1.3
V ₂ S ₄	42791	92731	49940	1.2
V ₃ S ₁	48556	74883	26328	0.5
V ₃ S ₂	45328	86080	40752	0.9
V ₃ S ₃	43714	81223	37510	0.9
V ₃ S ₄	42745	79290	36545	0.9

cultivation under spacing of 15 cm × 15 cm than all others was responsible for this result. The cultivar, Naveen when transplanted in the spacing of 15 cm × 15 cm *i.e.*, V₁ S₂ (1.52) and showed highest B:C ratio.

CONCLUSIONS

In this investigation, the combination of cultivar, Naveen with 15 cm × 15 cm spacing and cultivar, Naveen with 20 cm × 15

cm spacing provided statistically *at par* results of plant height at harvest, CGR at 30-60 DAT, no. of panicles m⁻². Transplanting of Naveen cultivar at 15 cm × 15 cm spacing also provided significantly superior results of panicle length (26.1 cm), no. of filled grains panicle⁻¹ (128.7) and grain yield (5.5 t ha⁻¹). The interaction of Naveen with 15 cm × 15 cm spacing showed highest HUE (0.00377 kg ha⁻¹ °C day hrs.⁻¹), HTUE (0.00040 kg ha⁻¹ °C day hrs.⁻¹), gross

return ($\square$ 120253 ha⁻¹), net return ($\square$ 74848 ha⁻¹) and B:C ratio (1.7). It can be concluded that transplanting of the rice cultivar, Naveen at 15 cm $\times$ 15 cm spacing is a better option for transplanted *Kharif* rice cultivation in southern Odisha to achieve higher yield and profit. Further research is required to find out the impact of transplanting of Naveen at 15 cm $\times$ 15 cm spacing with three or more seedlings hill⁻¹.

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