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Akanksha Sahu
M.Sc. (Ag.) Scholar, Section of Agronomy, D.K.S. College of Agriculture and Research Station, Bhatapara, IGKV, Raipur, Chhattisgarh, India

Hemant Lal Sonboir
Dean & Head of the section, Agronomy, D.K.S. College of Agriculture and Research Station, Bhatapara, IGKV, Raipur, Chhattisgarh, India

TL Kashyap
Professor, Section of Agronomy, D.K.S. College of Agriculture and Research Station, Bhatapara, IGKV, Raipur, Chhattisgarh, India

Manisha Sahu
Assistant Professor, Farm Machinery and Power Engineering, D.K.S. College of Agriculture and Research Station, Bhatapara, IGKV, Raipur, Chhattisgarh, India

Chandraprakash Verma
M.Sc. (Ag.) Scholar, Section of Agronomy, D.K.S. College of Agriculture and Research Station, Bhatapara, IGKV, Raipur, Chhattisgarh, India

Dev Singh Khushro
M.Sc. (Ag.) Scholar, Section of Agronomy, D.K.S. College of Agriculture and Research Station, Bhatapara, IGKV, Raipur, Chhattisgarh, India

Megha Karwar
M.Sc. (Ag.) Scholar, Section of Agronomy, D.K.S. College of Agriculture and Research Station, Bhatapara, IGKV, Raipur, Chhattisgarh, India

Piyush Rajak
M.Sc. (Ag.) Scholar, Section of Agronomy, D.K.S. College of Agriculture and Research Station, Bhatapara, IGKV, Raipur, Chhattisgarh, India

Corresponding Author:
Akanksha Sahu
M.Sc. (Ag.) Scholar, Section of Agronomy, D.K.S. College of Agriculture and Research Station, Bhatapara, IGKV, Raipur, Chhattisgarh, India

Effect of nitrogen levels and plant spacing on yield and economic returns of Sanjeevani rice (*Oryza sativa* L.) under Chhattisgarh conditions

Akanksha Sahu, Hemant Lal Sonboir, TL Kashyap, Manisha Sahu, Chandraprakash Verma, Dev Singh Khushro, Megha Karwar and Piyush Rajak

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Abstract

A field experiment was conducted during *Kharif* 2024 at the Instructional Farm, Dau Kalyan Singh College of Agriculture and Research Station, Bhatapara (C.G.) to evaluate the effect of nitrogen levels and plant spacing on grain yield, straw yield, harvest index and economic returns of rice (*Oryza sativa* L.) variety Sanjeevani. The experiment was arranged in a split plot design with three replications, comprising three spacings (20 × 10 cm, 20 × 15 cm, and 15 × 10 cm) and four nitrogen levels (0, 60, 80, and 100 kg N ha^{-1}). Results indicated that spacing and nitrogen levels significantly influenced both yield and economic parameters. Among spacings, 20 × 15 cm recorded the highest grain yield (2786 kg ha^{-1}), straw yield (5616 kg ha^{-1}) and harvest index (33.2%). Nitrogen application at 60 kg N ha^{-1} produced the highest grain yield (2670 kg ha^{-1}) and net returns (₹70,500 ha^{-1}) whereas, 100 kg N ha^{-1} increased straw yield (6170 kg ha^{-1}) but reduced economic efficiency. The highest gross returns (₹1,17,059 ha^{-1}), net returns (₹76,404 ha^{-1}) and B:C ratio (2.88) were achieved under 20 × 15 cm spacing. The interaction effect of spacing and nitrogen was non-significant for most economic parameters, though S_2N_2 (20 × 15 cm + 60 kg N ha^{-1}) combination recorded the highest profitability. Adoption of this combination is recommended for maximizing yield and economic returns under Chhattisgarh conditions.

Keywords: B:C Ratio, Economic Analysis, Grain Yield, Nitrogen, Rice, Spacing

Introduction

Rice (*Oryza sativa* L.) is the most important and extensively cultivated food crop worldwide, often called the "Global Grain." It serves as the staple food for more than half of the global population, contributing 32-59% of dietary energy and 25-44% of dietary protein in several Asian countries. Asia known as the "Rice Basket of the World" accounts for nearly 90% of global rice production and consumption, making rice central to food security and rural livelihoods. In India, rice occupies about 43 million hectares with an annual production of around 130 million tonnes, contributing significantly to the national food grain basket (Chowdhury *et al*., 2018) [2]. It is a vital component of agricultural GDP and rural economy, especially in states like Chhattisgarh, Odisha, West Bengal and Uttar Pradesh. Chhattisgarh known as the "Rice Bowl of India" has nearly 3.7 million hectares under rice cultivation, where it plays a critical role in food security and farmers livelihood (Anonymous, 2023) [1]. Nitrogen is a key nutrient influencing rice growth and productivity. However, improper nitrogen use often leads to poor nutrient-use efficiency, lodging and economic loss (Sinfield *et al*., 2010) [12]. Plant spacing another critical factor determines tiller population, photosynthetic efficiency and ultimately yield. The interaction of nitrogen management and optimum spacing thus holds great potential in improving both productivity and profitability (Siddiqui *et al.*, 1999) [11]. Economic analysis is equally important for evaluating crop management practices. Beyond yield maximization, farmers aim to achieve higher profitability, which depends on the balance between input cost and output value. Cost of cultivation, gross return, net return and benefit-cost ratio (B:C) are therefore essential indicators to assess the sustainability and economic viability of any agronomic practice.

Hence, the present investigation was undertaken to evaluate the effect of different nitrogen levels and plant spacing on yield and economics of rice under Chhattisgarh conditions.

Materials and Methods

The field experiment was conducted during Kharif 2024 at the Instructional Farm, DKS College of Agriculture and Research Station, Bhatapara (C.G.). The soil was sandy loam, low in nitrogen, medium in phosphorus and high in potassium. The experiment was laid out in a split plot design with three replications. Treatments included three spacings: S_1 (20 × 10 cm), S_2 (20 × 15 cm) and S_3 (15 × 10 cm) in the main plots and four nitrogen levels: N_1 (Control), N_2 (60 kg N ha^{-1}), N_3 (80 kg N ha^{-1}) and N_4 (100 kg N ha^{-1}) in sub-plots. Recommended agronomic practices were followed. Nitrogen was applied in three splits (basal, tillering and panicle initiation). Post-harvest observations included grain yield, straw yield, harvest index, gross returns, net returns and benefit-cost (B:C) ratio. Economic analysis was calculated using prevailing market prices and cost of cultivation for each treatment. Data were statistically analyzed using standard ANOVA and CD ($p \leq 0.05$) Gomez and Gomez (1984) [3].

Results and Discussion

Grain yield (kg ha^{-1})

The relevant data of grain yield were presented in Table 1. Grain yield was significantly influenced by spacing. The highest grain yield (2786 kg ha^{-1}) was recorded with S_2 (20 × 15 cm), which was significantly higher than other that of other spacing. On the other hand, significantly the lowest grain yield (2252 kg ha^{-1}) was observed in the treatment S_3 (15 × 10 cm). Regarding the nitrogen levels, grain yield was significantly influenced by nitrogen levels. The highest grain yield (2670 kg ha^{-1}) was obtained with N_2 (60 kg N ha^{-1}), which was at par with the treatment N_3 (80 kg N ha^{-1}) and significantly higher than other nitrogen levels. which was significantly higher than N_4 (100 kg N ha^{-1}) (2472 kg ha^{-1}). Application of nitrogen at the rate of 60 kg increased the grain yield by 22.81% over control. On the other hand, significantly the lowest grain yield (2174 kg ha^{-1}) was recorded in the control (N_1). The interaction effect between spacing and nitrogen levels was found to be non-significant.
The higher grain yield with 20 × 15 cm spacing might be due to optimum plant population per unit area, which facilitated better utilization of light, nutrients, and moisture, resulting in improved yield-attributing traits. Closer spacing (15 × 10 cm) caused more competition among plants. Similar findings have been reported by Paul *et al*. (2017) [8] and Kumar *et al*. (2018) [6]. Nitrogen application up to 60 kg N ha^{-1} significantly increased grain yield, possibly due to enhanced vegetative growth, increased tiller production, and higher panicle density. However, yield declined slightly at higher doses (80-100 kg N ha^{-1}) possibly due to excessive vegetative growth at the expense of grain formation.

Straw yield (kg ha^{-1})

The relevant data of straw yield were presented in Table 1. Straw yield was significantly influenced by spacing. The highest straw yield (5616 kg ha^{-1}) was recorded with S_2 (20 × 15 cm), which was at par with the treatment S_3 (5552 kg ha^{-1}), while significantly the lowest value (5068 kg ha^{-1}) was observed in S_1 (20 × 10 cm). Regarding the nitrogen levels, straw yield was significantly influenced by nitrogen levels. Significantly the highest straw yield (6170 kg ha^{-1}) was recorded with N_4 (100 kg N ha^{-1}), which was significantly superior to all other nitrogen levels. On the other hand, significantly the lowest straw yield (4807 kg ha^{-1}) was recorded in N_1 (control). The interaction effect between spacing and nitrogen levels was found to be non-significant.
The highest straw yield under 20 × 15 cm spacing may be attributed to better resource availability and vigorous vegetative growth. Higher nitrogen doses, increased straw yield due to increased plant height and biomass accumulation. These results are in agreement with Yasmin *et al*. (2018) [14] and Kumar *et al.* (2015) [5], who reported that nitrogen promotes vegetative growth and dry matter accumulation in rice.

Harvest index

The relevant data of harvest index were presented in Table 1. Harvest index was not significantly influenced by spacing. It ranged from 28.8% in S_3 (15 × 10 cm) to 33.2% in S_2 (20 × 15 cm). Significantly the highest harvest index (33.2%) was recorded under the treatment S_2 (20 × 15 cm). On the other hand, significantly the lowest harvest index (28.8%) was observed in the treatment S_3 (15 × 10 cm). Regarding the nitrogen levels, harvest index was significantly influenced by nitrogen levels, significantly the highest value (34.1%) recorded in N_2 (60 kg N ha^{-1}), followed by N_3 (31.2%) and N_1 (31.1%), whereas significantly the lowest harvest index (28.6%) was observed in N_4 (100 kg N ha^{-1}). The interaction effect between spacing and nitrogen levels was found to be non-significant.
Spacing did not significantly affect harvest index, suggesting that the proportion of economic yield to total biomass remained stable across different plant densities. Nitrogen significantly influenced harvest index, with the highest value at 60 kg N ha^{-1}, indicating better partitioning of dry matter to grain. At higher nitrogen doses (100 kg N ha^{-1}), harvest index decreased due to excessive vegetative growth and relatively lower grain formation. These findings align with the observations of Rajput *et al.* (2020) [9] and Kabat and Satapathy (2013) [4], who reported that excessive nitrogen favors straw production over grain yield.

Economic Analysis

The relevant data of economics, cost of cultivation (₹ ha^{-1}), gross returns (₹ ha^{-1}), net returns (₹ ha^{-1}) and B:C ratio were presented in Table 2.

Cost of Cultivation (₹ ha^{-1})

Among the spacing treatments, the highest cost of cultivation (₹ 42,599 ha^{-1}) was recorded with S_3 - 15 × 10 cm, followed by S_1 - 20 × 10 cm (₹ 41,384 ha^{-1}). The lowest cost of cultivation (₹ 40,655 ha^{-1}) was observed in S_2 - 20 × 15 cm. Regarding nitrogen levels, the highest cost of cultivation (₹ 42,424 ha^{-1}) was recorded with N_4 - 100 kg N, which was closely followed by N_3 - 80 kg N (₹ 41,926 ha^{-1}). The lowest cost of cultivation (₹ 40,410 ha^{-1}) was observed in N_1 - Control. The variation in cost of cultivation among different spacing treatments was mainly due to differences in plant population per unit area and associated input requirements. Narrower spacing (S_3 - 15 × 10 cm) required more seed and higher labour input for transplanting, which increased the cost of cultivation. Wider spacing (S_2 - 20 × 15 cm) reduced seed and transplanting costs without significantly compromising yield, leading to better economic efficiency.

Gross Returns (₹ ha^{-1})

Spacing significantly influenced the gross returns of rice. The highest gross returns (₹ 1,17,059 ha^{-1}) were obtained in S_2 - 20 × 15 cm, which was significantly superior over other spacings. The lowest gross returns (₹ 95,635 ha^{-1}) were recorded in S_3 - 15 × 10 cm. Regarding nitrogen levels, the highest gross returns (₹ 1,11,923 ha^{-1}) were recorded with N_2 - 60 kg N, followed by N_3 - 80 kg N (₹ 1,06,121 ha^{-1}). The lowest gross returns (₹ 91,776 ha^{-1}) were observed in N_1 - Control.

Net Returns (₹ ha^{-1})

Net returns were also significantly affected by spacing and nitrogen levels. The highest net returns (₹ 76,404 ha^{-1}) were recorded in S_2 - 20 × 15 cm, followed by S_1 - 20 × 10 cm (₹ 57,088 ha^{-1}). The lowest net returns (₹ 53,036 ha^{-1}) were observed in S_3 - 15 × 10 cm. Among nitrogen levels, the highest net returns (₹ 70,500 ha^{-1}) were obtained with N_2 - 60 kg N, followed by N_3 - 80 kg N (₹ 64,195 ha^{-1}). The lowest net returns (₹ 51,366 ha^{-1}) were recorded under N_1 - Control.

Benefit-Cost (B:C) Ratio

The benefit-cost ratio was highest (2.88) with S_2 - 20 × 15 cm, followed by S_1 - 20 × 10 cm (2.38). The lowest B:C ratio (2.24) was observed in S_3 - 15 × 10 cm. With respect to nitrogen levels, N_2 - 60 kg N recorded the highest B:C ratio (2.71), followed by N_3 - 80 kg N (2.54). The lowest B:C ratio (2.28) was found under N_1 - Control.

Interaction Effect

The interaction of spacing and nitrogen on economic parameters was mostly non-significant, although the S_2N_2 combination gave the highest profitability. This indicates that choosing optimum spacing and moderate nitrogen level is key to maximizing economic returns without excessive fertilizer costs.

Discussion

Gross and net returns were maximized in S_2 - 20 × 15 cm because this spacing achieved a balance between adequate plant population and efficient utilization of sunlight, nutrients, and space, resulting in higher grain yield and economic returns. Regarding nitrogen levels, N_2 - 60 kg N produced the highest gross returns, net returns, and B:C ratio, indicating that moderate nitrogen application was more profitable than higher doses. Excess nitrogen in N_3 and N_4 increased cultivation costs without proportionally increasing yields, reducing profitability. The lowest economic returns were associated with N_1 - Control due to reduced yield from nitrogen deficiency.

These results suggest that 20 × 15 cm spacing with 60 kg N ha^{-1} indicate that moderate nitrogen combined with optimal spacing not only maximizes yield but also improves economic efficiency in line with findings of Sharma *et al.* (2018) [10].

Table 1: Grain yield, straw yield and harvest index of rice as influenced by spacing and nitrogen levels

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index (%)
Spacing			
S_1 - 20 × 10 cm	2335	5068	31.7
S_2 - 20 × 15 cm	2786	5616	33.2
S_3 - 15 × 10 cm	2252	5552	28.8
S.Em ±	73	108	0.9
CD (P = 0.05)	288	426	NS
Nitrogen levels			
N_1 - Control	2174	4807	31.1
N_2 - 60 kg N	2670	5127	34.1
N_3 - 80 kg N	2514	5543	31.2
N_4 - 100 kg N	2472	6170	28.6
S.Em ±	57	106	0.7
CD (P = 0.05)	170	315	2.0
Nitrogen levels at same level of spacing			
S.Em ±	147	216	1.2
CD (P = 0.05)	NS	NS	NS
Spacing at same or different levels of nitrogen			
S.Em ±	113	192	1.4
CD (P = 0.05)	NS	NS	NS

Table 2: Economics of rice at different growth stages as influenced by spacing and nitrogen levels

Treatments	Cost of Cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
Spacing				
S_1 - 20 × 10 cm	41384	98471	57088	2.38
S_2 - 20 × 15 cm	40655	117059	76404	2.88
S_3 - 15 × 10 cm	42599	95635	53036	2.24
S.Em ±	-	2934	2934	0.07
CD (P = 0.05)	-	11829	11829	0.28
Nitrogen levels				
N_1 - Control	40410	91776	51366	2.28
N_2 - 60 kg N	41423	111923	70500	2.71
N_3 - 80 kg N	41926	106121	64195	2.54
N_4 - 100 kg N	42424	105068	62644	2.48
S.Em ±	-	2293	2293	0.06
CD (P = 0.05)	-	6812	6864	0.16
Nitrogen levels at same level of spacing				
S.Em ±	-	5868	5868	0.13
CD (P = 0.05)	-	NS	NS	NS
Spacing at same or different levels of nitrogen				
S.Em ±	-	4520	4520	0.10
CD (P = 0.05)	-	NS	NS	NS

Conclusion

Adopting 20 × 15 cm spacing with 60 kg N ha^{-1} maximizes grain yield, harvest index and economic returns of rice variety Sanjeevani under Chhattisgarh plains. Higher nitrogen (100 kg ha^{-1}) enhances straw yield but is less efficient economically. The S_2N_2 combination is recommended for farmers seeking both high productivity and profitability.

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