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Productivity and Profitability of *kharif* Rice (*Oryza sativa* L.) under Seedling Age and Nitrogen Management

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The aim of the experiment is to know the effect of seedling age and nitrogen management on growth, yield attributes, yield and economics of *kharif* rice.
Study Design: The experiment was laid out in split-plot design.
Place and Duration of Study: Research Farm of Agricultural Research Station, Brinjhagiri, Chhatabar of Faculty of Agricultural Sciences, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar (Odisha), during *kharif* season of 2023.
Methodology: Three seedling ages viz. S_1: 3 weeks (21 days), S_2: 4 weeks (28 days) and S_3: 5 weeks (35 days) as main plot treatment and four nitrogen management strategies i.e. N_1: 100% N through urea, N_2: 50% N through urea + 50% N through neem cake, N_3: 50% N through urea + 50% N through FYM and N_4: 50% N through FYM + 50% N through neem cake as sub-plot treatments replicated thrice. The net plot size was 4m × 3m.

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Results: S_2 resulted highest grain yield (4.74t ha^{-1}) and straw yield (7.18t ha^{-1}). N_1 produced highest grain yield (4.54t ha^{-1}) and straw yield (6.96t ha^{-1}). Maximum net return (Rs.60367) and return per rupee investment (1.98) received from 4 weeks old seedling with 100% N through urea application.

Conclusion: Transplantation of 4 weeks old seedling (28 days) and 50% N through urea + 50% N through neem cake can be recommended to achieve higher yield. Maximum net return (Rs.60367), gross return (Rs.121687) and return per rupee investment (1.98) received from 4 weeks old seedling with 100% N through urea application.

Keywords: Kharif rice; seedling age; nitrogen management; yield and economics.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple food for over half of the world's population, particularly in Asia, where about 90% of the total rice is produced and consumed. India is the second largest producer and consumer of rice in the world. In India, rice occupies an area of 43.86 M ha with an annual production of 117.94 Mt (DAC & FW, 2019-20) [1]. It serves as a primary source of food grain for billions of people, highlighting its significance in global food security. Rice production in India has shown significant progress over the years, but it has faced unprecedented challenges due to environmental degradation and climate change in recent years [2]. Though rice production in India has shown significant progress over the years, it has faced unprecedented challenges due to environmental degradation and climate change in recent years. The necessity for integrated nitrogen management practices that combine chemical fertilizers with organic sources towards sustainability becoming an important approach for improving nutrient uptake efficiency, enhancing soil health, and reducing the negative impacts of chemical fertilizers on the environment.

The age of seedlings used for growing rice can have a significant impact on the overall crop yield and quality. The effect of seedling age on rice crop is a critical factor that farmers need to consider when planning their cultivation practices. One of the primary reasons why seedling age is essential in rice cultivation is its impact on the maturity and growth rate of the crop. Younger seedlings have higher tillering potential which drastically decreases with age. Younger seedlings produce more yield in comparison to older seedlings [3]. Transplanting 20 days old seedlings has been commonly reported to generate an increase in grain yield as a result of higher tiller production [4]. Nitrogen is identified as the most essential nutrient for rice production, crucial for achieving high yields. It promotes plant growth, enhances grain yield and quality, and is involved in various physiological processes such as tillering and protein synthesis. Despite the benefits of nitrogen fertilizers, their excessive use can lead to environmental issues and soil degradation. Farmers often apply large amounts of nitrogen through chemical fertilizer to maximize yields, but only a fraction (20-50%) is effectively utilized by the crop. Nitrogen, a key element for crop growth, has a significant impact on agricultural output. A sufficient nitrogen supply increases the synthesis of chlorophyll, the green pigment responsible for photosynthesis. Chlorophyll absorbs and converts sunlight into energy, enabling plants to produce carbohydrates and drive vegetative growth. The introduction highlights the necessity for integrated nitrogen management practices that combine chemical fertilizers with organic sources towards sustainability. This approach aims to improve nutrient uptake efficiency, enhance soil health, and reduce the negative impacts of chemical fertilizers on the environment. A split application of nitrogen fertilizer improved yields by 23-30% when combined with younger seedlings [5]. On the above background, the experiment was conducted with the objective to know the effect of seedling ages and nitrogen management on growth, yield attributes, yield and economics of *kharif* rice. This paper examines the influence of seedling age and nitrogen fertilizer on the growth and yield of rice. The findings may assist farmers in selecting optimal seedling ages to enhance their yields. I propose that, with the incorporation of the necessary revisions and recommendations, this could be beneficial to both the scientific community and agricultural producers.

2. MATERIALS AND METHODS

A field experiment was carried out at the Agricultural Research Station in Brinjhagiri, Chatabar of the Faculty of Agricultural Sciences at Siksha ‘O’ Anusandhan (Deemed to be University), Bhubaneswar, Odisha during the *kharif* season of 2023. The location situated in the South east coastal plain Zone of India. The field where the experiments was conducted is located at Latitude 20.46º N and Longitude 85.67º E. The soil of the experimental field was sandy loam soil, slightly acidic with pH 5.78, EC 7.33 ds m^{-1}, soil organic carbon 0.41% and with 258.6 kg ha^{-1}, 20.29 kg ha^{-1},138.4 kg ha^{-1} available NPK respectively (Table 1). The experimental rice variety, CR Dhan 205 an aerobic rice variety released by NRRI, Cuttack. The duration of CR Dhan 205 was observed 115 days in this experiment. The experiment followed a split-plot design with three replications. The net plot size was 4m × 3m. The main plot treatment involved three seedling ages viz. S_1: 3 weeks old seedling (21 days), S_2: 4 weeks old seedling (28 days) and S_3: 5 weeks old seedling (35 days) and the subplot treatment involved four nitrogen management strategies i.e. N_1: 100% N through urea, N_2: 50% N through urea + 50% N through neem cake, N_3: 50% N through urea + 50% N through FYM and N_4: 50% N through FYM + 50% N through neem cake. The nursery bed was prepared and rice was sown on June 27th, 2023. A recommended nutrient dose of 60:30:30 kg/ha N, P_2O_5, K_2O was applied. The source of N, P_2O_5, K_2O was urea, Single Super Phosphate (SSP) and Muriate of Potassium (MOP) respectively. Half of N along with full dose of P and K were applied as basal and mixed with the soil of the individual plots. Different fertilizer and manure doses were applied depending on the treatment allocated. Seedlings of varying ages were transplanted on the following dates: July 18th (S_1: 21 days old seedling), July 25th (S_2: 28 days old seedling), and August 1st (S_3: 35 days old seedling), with a row spacing of 20 cm and a plant spacing of 10 cm. The biometric data like plant height (cm) and number of tillers per plant was taken at an interval 30 days and yield related data like, number of effective tillers per hill, number of grains per panicle, panicle weight, test weight (g), grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}) was taken during maturity period. The harvest index and economics of cultivation were calculated. The data obtained as described earlier were subjected to statistical analysis by the Analysis of Variance method [6]. The economics is calculated using the formula-

Net Return = Gross Return – Cost of Cultivation

3. RESULT AND DISCUSSION

3.1 Biometric Parameters

The findings indicate that the treatment involving S_2, which consisted of 4-week-old seedlings (28 days), resulted in the tallest plants, measuring 102.0 cm, and the highest average number of tillers per hill, recorded at 13.91. In contrast, the S_3 treatment, utilizing 5-week-old seedlings (35 days), yielded the shortest plants at 94.5 cm and the lowest average number of tillers per hill, which was 12.05, as detailed in Table 2. This observation aligns with the conclusions drawn by Rajendran et al. [7] who noted that older seedlings tend to exhibit slower recovery rates. Research has shown that younger seedlings tend to produce significantly taller plants and a higher number of tillers compared to older seedlings. This finding highlights the importance of considering seedling age when aiming to optimize plant growth and tillering in agricultural practices [8,9]. Among nitrogen management, 100% N through urea (N_1) attained the tallest plant (104.4cm) followed by 50% N through urea + 50% N through neem cake (N_2) (101.4cm) and the maximum number of tillers per hill (14.32) with N_1 treatment, followed by 50% N through urea + 50% N through neem cake (N_2) (13.02). Whereas, at maturity, 50% N through FYM + 50% N through neem cake (N_4) produced the smallest plant (91.9cm) and the lowest number of tillers per hill (11.99) (Table 2). The highest plant height was observed with chemical fertilizers. It may be due to the fast release of nutrients by chemical fertilizer and plant unable to uptake it readily [10]. Also, in nitrogen application from inorganic sources increases plant height faster than inorganic and organic combinations because of the faster availability [11]. The higher number of tillers recorded with chemical + Organic fertilizer was statistically at par with 100% chemical fertilizer application [12].

3.2 Yield and Yield Attributes

The treatment involving S_2, which consisted of 4-week-old seedlings (28 days), resulted in the highest number of effective tillers per hill (8.57), number of grains per panicle (111.92), panicle weight (2.50g) and test weight (22.29g). The lowest effective tillers per hill (7.78) and number of grains per panicle (106.42) observed in S_3, and S_1 treatment resulted in the lowest panicle weight (2.30g) and test weight (21.31g) indicated in Table 2 and Fig. 1. S_2: 4 weeks old seedling (28 days) showed the significantly highest grain yield (4.74t ha^{-1}) straw yield (7.18 t ha^{-1}) and harvest index (0.40) while S_3: 5 weeks old seedling (35 days) had the lowest grain yield (4.03t ha^{-1}), straw yield (6.18t ha^{-1}) and harvest index (0.39) indicated in Table 3 and Fig. 1. Young seedlings showed superior yield attributes and overall performance in rice cultivation, emphasizing the significance of seedling age in maximizing crop yield and quality over aged seedling [13]. Dhungana et al., [14] revealed that there was greater effective tiller per hill in the plant of younger seedlings than older ones. The significant reduction in total tillers production with delay in planting [15]. The highest test weight was observed in 28 days old seedlings. This increase in test weight among younger seedlings may be due to a higher number of filled grains per panicle and longer panicles [16,17,18].

In terms of nitrogen management, it was observed that applying 100% nitrogen through urea (N_1) resulted in the highest number of effective tillers per hill (8.74), highest test weight (22.23 g) was recorded for N_1. The lowest number of effective tillers per hill (7.44) and test weight (21.28g) were recorded for 50% N through urea and 50% N through FYM (N_3). 50% N through FYM + 50% N through neem cake (N_4) resulted in the highest number of grains per panicle (113.33) and highest panicle weight (2.5g) was recorded in the 100% N through urea (N_1) treatment, while the treatment

Table 1. Physico-chemical properties of the experimental soil

Properties	Value	Method used
Mechanical composition Sand (%) Silt (%) Clay (%)	 70.2 21.3 8.5	 International pipette method (Jackson, 1973)
Soil texture	Sandy loam soil	USDA system (Brady, 1974)
pH	5.78	(Jackson, 1973)
Electrical conductivity (dS m^{-1})	1.33	(Jackson, 1973)
Organic carbon (%)	0.41	Walkley and Black method (Jackson, 1973)
Available nitrogen (kg/ha)	258.60	Alkaline permanganate method (Jackson, 1973)
Available phosphorus (kg/ha)	20.29	Olsen's method (Olsen et al., 1954)
Available potassium (kg/ha)	138.40	Flame photometric method (Jackson, 1973)

Table 2. Effect of seedling age and nitrogen management on plant height (cm), no. of tillers/hill, no. of effective tillers/hill, panicle weight (g) and test weight (g) on *kharif* rice

Treatment	Plant height (cm)	No. of tillers/ hill	No. of effective tillers/hill	No of grains/ panicle	Panicle weight	Test weight
S_1: 3 weeks (21 days)	98.68	13.04	8.28	107.83	2.30	21.31
S_2: 4 weeks (28 days)	101.98	13.91	8.57	111.91	2.50	22.29
S_3: 5 weeks (35 days)	94.54	12.04	7.78	106.41	2.33	21.90
SEm (±)	0.58	0.24	0.08	3.00	0.10	0.73
CD (p = 0.05)	2.30	0.96	0.31	11.79	0.40	2.86
N_1: 100% N through urea	104.36	14.32	8.74	112.55	2.50	22.23
N_2: 50% N through urea + 50% N through neem cake	101.42	13.03	8.14	107.22	2.34	21.80
N_3: 50% N through urea + 50% N through FYM	95.96	12.66	7.40	101.78	2.17	21.28
N_4: 50% N through FYM + 50% N through neem cake	91.88	11.99	8.50	113.33	2.50	22.02
SEm (±)	0.71	0.43	0.10	2.22	0.08	0.39
CD (p = 0.05)	2.77	1.70	0.38	8.73	0.32	1.54

N: Nitrogen; FYM: Farm Yard Manure

Table 3. Effect of seedling age and nitrogen management on grain yield (t/ha), straw yield (t/ha), biological yield (t/ha) and harvest index on *kharif* rice

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest Index
S_1: 3 weeks (21 days)	4.32	6.63	10.96	0.39
S_2: 4 weeks (28 days)	4.74	7.18	11.92	0.40
S_3: 5 weeks (35 days)	4.03	6.17	10.20	0.39
SEm (±)	0.13	0.24	0.61	0.01
CD (p = 0.05)	0.51	0.96	2.40	0.06
N_1: 100% N through urea	4.54	6.96	11.50	0.39
N_2: 50% N through urea + 50% N through neem cake	4.44	6.74	11.19	0.40
N_3: 50% N through urea + 50% N through FYM	4.30	6.60	10.90	0.39
N_4: 50% N through FYM + 50% N through neem cake	4.17	6.35	10.52	0.39
SEm (±)	0.05	0.08	0.25	0.01
CD (p = 0.05)	0.19	0.32	0.96	0.04

N: Nitrogen; FYM: Farm Yard Manure

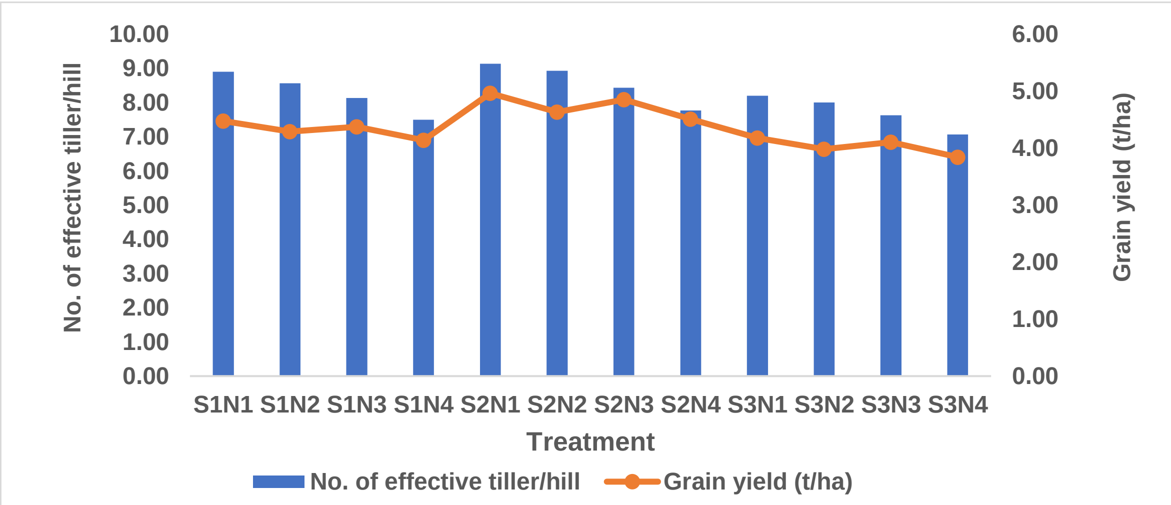

Fig. 1. Effect of Effect of seedling age and nitrogen management on no. of effective tillers/hill and grain yield (t/ha)

with 50% N through urea + 50% N through FYM (N_3) had the lowest number of grains per panicle (101.78) and the lowest panicle weight (2.17g). The highest grain yield (4.54t ha^{-1}) and straw yield (6.96t ha^{-1}) were found when using 100% N through urea (N_1) application whereas highest harvest index (0.40) was achieved with 50% N through urea + 50% N through neem cake (N_2). The lowest grain yield (4.17t ha^{-1}), straw yield (6.35t ha^{-1}) and harvest index (0.39) were obtained from 50% N through FYM + 50% N through neem cake (N_4) treatment (Table 3). When inorganic nitrogenous fertilizers were combined with organic sources like FYM, there was a significant increase in the number of effective tillers per hill, especially with 100% RDF combined with FYM [19]. The combination of organic and inorganic nitrogen sources can improve growth parameters such as the number of leaves, tillers, and panicles, as well as increase test weight [20]. A positive impact of applying 100% N from organic sources on the growth and yield attributes of rice [21]. Yield increment in full chemical application as well as integration with chemical + organic was observed [22,23]. Reshma et al., [24] reported that treatments with 50% organic and 50% inorganic fertilizers yielded higher as compared to results of 100% inorganic applications, indicating effective nutrient management.

Table 4. Effect of seedling age and nitrogen management on economics of *kharif* rice

Treatments	Cost of Cultivation (₹)	Gross Return (₹)	Net Return (₹)	Return per rupee investment
S_1N_1: 3 weeks old seedling with 100% N through urea	60370	109763	49393	1.82
S_1N_2:3 weeks old seedling with 50% N through urea + 50% N through neem cake	74705	107220	32515	1.44
S_1N_3: 3 weeks old seedling with 50% N through urea + 50% N through FYM	64205	105300	41095	1.64
S_1N_4 :3 weeks old seedling with 50% N through FYM + 50% N through neem cake	78540	101620	23080	1.29
S_2N_1: 4 weeks old seedling with 100% N through urea	61320	121687	60367	1.98
S_2N_2: 4 weeks old seedling with 50% N through urea + 50% N through neem cake	75655	118800	43145	1.57
S_2N_3: 4 weeks old seedling with 50% N through urea + 50% N through FYM	65155	113510	48355	1.74
S_2N_4: 4 weeks old seedling with 50% N through FYM + 50% N through neem cake	79490	110657	31166	1.39
S_3N_1: 5 weeks old seedling with 100% N through urea	62270	102530	40260	1.65
S_3N_2: 5 weeks old seedling with 50% N through urea + 50% N through neem cake	76605	100570	23965	1.31
S_3N_3: 5 weeks old seedling with 50% N through urea + 50% N through FYM	66105	97700	31595	1.48
S_3N_4: 5 weeks old seedling with 50% N through FYM + 50% N through neem cake	80440	94272	13832	1.17
SEm (±)		86	39	
CD (p = 0.05)		345	157	

N: Nitrogen; FYM: Farm Yard Manure; ₹: Indian currency Rupees

3.3 Cost of Cultivation

The cost of cultivation, gross return, net return and return per rupees invested will vary depending on the age of the seedlings and nitrogen management practices (Table 4). The cost of cultivation is highest for the treatment S_2N_4 (₹79490.40) and the lowest cost of cultivation is calculated in S_1N_1(₹60370). Gross return received highest for S_2N_1 (₹121687) and lowest for S_3N_4 (₹94272). Net return and return per rupee investment were calculated highest for S_2N_1 (₹60367 and 1.98 respectively) and lowest for S_3N_4 (₹13832 and 1.17 respectively).

4. CONCLUSION

Transplantation of 4 weeks (28 days) old seedling produced highest yield and 50% N through urea + 50% N through neem cake can be recommended to achieve higher yield. Maximum net return (₹60367), gross return (₹ 121687) and return per rupee investment (1.98) received from 4 weeks old seedling with 100% N through urea application.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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