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Evaluation of Different Varieties and Nitrogen Levels on Growth and Yield of Black Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The field experiment was conducted at Crop Research Farm during *kharif* season, in the Department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj Uttar Pradesh. The experiment comprised three varieties *viz*., Chakhao Poireiton (V_1), Chakhao Amubi (V_2) and Chakhao Angangba (V_3); and three rates of nitrogen *viz.*, 60 kg/ha (N_1), 70 kg/ha (N_2) and 80 kg/ha (N_3). The experiment was laid out in a randomized block design with three replications. The growth analysis result was observed with the application of [Chakhao Poireiton and nitrogen (80 kg/ha)] produces higher plant height (142.53 cm), maximum number of tillers/hill (13.97), higher plant dry weight (32.49 g), higher panicle length (30.1 cm), maximum number of grains/panicle (153.60), higher test weight (24.01 g), higher grain yield (5.67 t/ha), higher straw yield (11.27 t/ha). However, the maximum gross return (2,38,070.00 INR/ha), maximum net return (1,89,800.00 INR/ha) and maximum benefit cost ratio (3.23) was also obtained with the same treatment 3 [Chakhao Poireiton + nitrogen (80 kg/ha)].

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1. INTRODUCTION

"Rice (*Oryza sativa* L.) is the most important cereal crop in the developing world and is the most staple food of over half the world's population. It is generally considered a semi-aquatic annual grass plant. About 20 species of the genus Oryza are recognized, but nearly all cultivated rice is *O. sativa L*, family of Gramineae. 35-60% of the total calorie approximately one-fifth of all calories consumed by humankind" [1]. "Presently more than 90% of total rice production and consumption is in Asia. In Asia, above two billion people receive 60-70 % of their energy necessities from rice" (Sridhar et al., 2019). "Rice is the primary source of energy for over half of the world's people. Rice flour is rich in starch and is used for making various food materials. The starch content of the rice plant is generally low during the early growth stages and increases toward flowering. Generally, before flowering, the starch accumulates in the leaf sheath and culm, but after flowering, it accumulates in the panicle. Much of the starch accumulated in the leaf sheath and culm before flowering is translocated into the grains during ripening" [2]. "Carbohydrates produced by photosynthetic tissues is either transported to other organs as soluble sugars, or accumulated in leaves as soluble sugars and starch during the different growth stages. Soluble carbohydrates and starch, which accumulates under normal conditions before the stress commonly, constitute the main resources for plants to supply energy during stress condition. It is also used in some instances by brewers to make alcoholic malt. Likewise, rice straw mixed with other materials is used to produce porcelain, glass and pottery. Rice is also used in manufacturing of paper pulp and livestock bedding" [3]".

"Black rice is a type of the rice species *Oryza sativa* L. which is glutinous, packed with high level of nutrients and mainly cultivated in Asia. Black rice is also known as purple rice, forbidden rice, heaven rice, imperial rice, king's rice and prized rice" [4]. "This rice includes several varieties with a long history of cultivation in Southeast Asian countries such as China, India and Thailand. There are more than 200 types of black rice varieties in the world. Only China is responsible for 62 % of global production of black rice and it has developed more than 54 modern black rice varieties with high yield characteristics and multiple resistances. China cultivates most of the black rice followed by Sri Lanka, Indonesia, India and Philippines etc. Thailand occupies the ninth position for black rice cultivation. In India, Black rice is cultivated only in few areas especially Manipur –the North Eastern States of India. Black rice is a medium size grain, non-glutinous heirloom rice" [4]. "Black rice has a dark purplish -Black colour with a nutty, slightly sweet flavour. Black rice is black due to the presence of the Black colour pigment called anthocyanin which contain high amounts of certain antioxidants. Black rice also has higher levels of protein, vitamins and minerals. Compared to white rice, black rice is relatively rich in mineral content such as Fe, Zn, Mn and P and has a high variability in mineral content that depends on varieties and soil types of the planting area" [5]. Supplementation of black scented rice in the diet will have a great impact on human health. A health benefit of black rice includes prevention of cancer, diabetes, heart diseases, Alzheimer's disease, gallstones etc. Black rice is picking up in more health food stores.

In world rice growing in 165.12 million ha, the production is 509.42 million tonnes and the yield is about 4.61 metric tons/ha" [6]. "Among the rice growing countries of the world, India has the largest rice acreage and ranked second in production after wheat in the world. In India rice is grown in 45.07 million ha, the production level is 122.27 million tones and the yield is about 2713 kg/ha" [7]. "In Uttar Pradesh state ranks third in the country in production of rice. it grown over area about 5.68 m/ha which comprise of (13.5%) of total rice in India. Annual rice production is around 15.66 million metric tonnes, the average yield is 2759 kg/ha" [7].

"Nitrogen deficiency is one of the major constraints to crop production. The unique feature of N is its soils having very low soil organic matter ontent, soils with particular constraints on indigenous N supply, high potential of ammonia (NH_3). Due to a deficiency of N, older leaves turn an orange-yellow color and die from the tip down; young leaves are thin, short, and rigid. Similarly, a deficiency of N causes a decrease in plant height and the number of tillers. The roots decrease in number and become slender and lengthy. It is one of Asia's most prevalent rice concerns and frequent in all rice-growing soils where modern varieties are planted in the absence of adequate mineral

N fertilizer. It frequently occurs during important growth stages of the plant, such as tillering and panicle initiation" [8].

"The Black rice variety Chakhao Poireiton is cultivated by most of the farmers (43%) because of its higher productivity and delicacy. As per local belief, black rice was first cultivated by the 12th Meitei king Poireiton Khunthokpa during 38-18 BC in his capital Poi located at the foothills of Heirok range. Thus the rice landrace came to be known as Chakhao poireiton. Black rice plants attain 136-166 cm height which was comparatively higher than the other traditional non-black rice varieties cultivated in the study area. Chakhao amubi was the tallest black rice. The highest panicle length number of grains, and tillers were recorded for Chakhao poireiton. The kernel length of Chakhao amubi and Chakhao poireiton are considerd as long and medium" [9]. Chakhao poireiton and Chakhao amubi, were shown to have high anthocyanin and phenolics content and strong antioxidant activity. Chakhao poireiton was classified as waxy, as their amylose content was less than (2%). Chakhao Amubi and Chakhao Angangba was with very low amylose content (3.16%). The black chakhao cultivars are quite tall in height. Majority of chakhao cultivars ranges in height between 130-165cm and flowering is initiated between 95-116 DAT. The rice culture Chakhao Poireton is a good alternative variety, it exhibits high yield potential (5-6 t/ha) and milling 60-70%.

"Nitrogen is an essential nutrient element for plants and is necessary for photosynthesis, growth and development, yield, quality, and biomass production in rice. Nitrogen promotes rapid plant growth and increases grain yield and quality by increasing tillering, leaf area development, grain formation, grain filling, and protein synthesis. Nitrogen is highly mobile within the plants and soil. During the early and mid-tillering, panicle initiation, booting, and grain development phases of ripening, N is the most typically required nutrient element" [10]. "N has an important role in the creation of rice quality. Increasing N fertilization can help improve the nutritional quality and processing quality of rice, but excessive N fertilization can increase rice chalkiness and worsen the rice appearance quality, cooking and eating quality" [11]. "In order to optimize rice yield, different agricultural practices are applied and one of them is fertilizer application. Among the major nutrient elements, nitrogen (N) is the most important and limiting nutrient for rice crop growth and yield which is required in higher amounts compared to other nutrients" [12]. "Nitrogen (N) influences rice yield by playing major role in the photosynthesis, biomass accumulation, effective tillering, and spikelets formation" [13]. Keeping in view the above facts, the experiment was conducted to find out the "Evaluation of different varieties and nitrogen levels on growth and yield of Black Rice (*Oryza sativa* L.)".

2. MATERIALS AND METHODS

"The field experiment was conducted during *kharif* season 2022 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology And Sciences, Prayagraj (U.P.). The soil of the experimental field was sandy loam in texture, nearly neutral in soil reaction (pH 8), organic carbon level in medium condition (0.87%), medium available N (225 Kg/ha), high in available P (41.8 kg/ha) and medium available K (261.2 kg/ha)" [14]. The experiment was laid out in Randomized Block Design with three replication having two factors viz. three black rice varieties (Chakhao poireiton, Chakhao Amubi, Chakhao Angangba) and three Nitrogen levels (60, 70, 80 kg/ha). The three varieties of black rice with 118days duration was used for this experiment. Twenty-five days old seedling were transplanted at plant spacing 20x15 cm with 2-3 seedling per hill. The treatment combinations are treatment 1- Chakhao Poireiton + Nitrogen (60 kg/ha), treatment 2- Chakhao Poireiton + Nitrogen (70 kg/ha), treatment 3- Chakhao Poireiton + Nitrogen (80 kg/ha), treatment 4- Chakhao Amubi + Nitrogen (60 kg/ha), treatment 5- Chakhao Amubi + Nitrogen (70 kg/ha), treatment 6- Chakhao Amubi + Nitrogen (80 kg/ha), treatment 7- Chakhao Angangba + Nitrogen (60 kg/ha), treatment 8- Chakhao Angangba + Nitrogen (70 kg/ha), treatment 9- Chakhao Angangba + Nitrogen (80 kg/ha). All agronomic practices are followed in order in the crop period. Experimental data collected was subjected to statistical analysis of variance (ANOVA) as outlined by Gomez and Gomez [15]. Critical Difference (CD) values were calculated wherever the 'F' test was found significant at 5 percent level.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height (cm)

The data revealed that a significantly higher plant height (142.53) was recorded in treatment 3

[Chakhao poireiton + Nitrogen (80kg/ ha)]. However, treatment 2 [Chakhao poireiton + Nitrogen (70kg/ ha)] was found to be statistically at par with treatment 3 [Chakhao poireiton + Nitrogen (80kg/ ha)] (Table 1). The significant and higher plant height was observed with the variety Chakhao Poireiton might be due to differences in the genetic makeup of the varieties and their response ability to different levels of fertilizer applied. This finding is similar reported by Ndaeyo et al. [16]. Further increase in plant height nitrogen (80 kg/ha) might be due to enough nutrition (NP) in termed of possible increase in nutrient absorption capacity of plant as a result of better root development and increased translocation of carbohydrates from source to growing points. These results confirmed the finding of Bhiah et al. [17].

3.1.2 Number of tillers/hill

The data revealed that a significantly maximum number of tillers/hill (13.97) was recorded in treatment 3 [Chakhao poireiton + Nitrogen (80kg/ ha)] (Table 1). The significant and maximum number of tillers/hill was observed with the variety Chakhao Poireiton might be due to varietal variation and their genetic characters attributed to greater translocation of photosynthates to the reproductive part of the plant. Similar result was reported by Thenmozhi et al., [18]. Further increase number of tillers was observed with the application of N (80 kg/ha) might be due to increase levels of nitrogen favours greater absorption of nutrients resulting in rapid expansion of foliage, better accumulation of photosynthates. Similar result was reported by Murthy et al. [19].

3.1.3 Plant dry weight (g/hill)

The data revealed that a significantly higher plant dry weight (32.93 g) was recorded in treatment 3 [Chakhao poireiton + Nitrogen (80kg/ ha)]. However, treatment 2 [Chakhao poireiton + Nitrogen (70kg/ ha)] was found to be statistically at par with treatment 3 [Chakhao poireiton + Nitrogen (80kg/ ha)] (Table 1). The significant and higher plant dry weight was observed with the variety Chakhao Poireiton of black rice might be due to their genetic potential and differential plant height and more number of tillers/hill. Similar result was reported by Dillep et al. [20]. Further higher plant dry weight was observed with Nitrogen (80 kg/ha) might be due to nitrogen is the main component of the protoplasm involves in various metabolic processes *viz.* photosynthesis, stimulation of cell division and elongation, resulted increased plant dry weight. Similar result was reported by Meena et al. [21].

3.1.4 Crop growth rate (g/m^2/day)

The data revealed that a significantly higher Crop Groeth Rate (13.50 g/m^2/day) was recorded in treatment 9 [Chakhao Angangba+ Nitrogen (80 Kg/ha)] as compared to other treatments. However, the treatment 2 [Chakhao Poireiton + Nitrogen (70 Kg/ha)], treatment 3 [Chakhao Poireiton + Nitrogen (80 Kg/ha)] and treatment 7 [Chakhao Angangba+ Nitrogen (60 Kg/ha)] were found statistically at par with treatment 9 [Chakhao Angangba+ Nitrogen (80 Kg/ha)] (Table 1). The significant and higher crop growth rate was observed with the variety Chakhao Angangba might be due to the natural endowments of crop cultivars to optimally utilize available nutrients and subsequently partition its photosynthates. Similar result was reported by Ndon and Ndaeyo [22]. Further significant and higher crop growth rate was observed with Nitrogen (80 Kg/ha) might be due to the role of nitrogen in production and translocation of cytokinin from the root to the shoots increases cell division rate and the growth of rice with the increased in nitrogen level. Similar result was reported by Azarpour et al. [23].

3.1.5 Relative growth rate (g/g/day)

The data revealed that a significantly higher Relative Growth Rate (0.0169 g/g/day) was observed and recorded in treatment 9 [Chakhao Angangba + Nitrogen (80 Kg/ha)] as compared to other treatments (Table 1). The significant and higher relative growth rate was observed with the variety Chakhao Angangba might be due to increase in photosynthetic tissues and faster vegetative growth, which may have leads to higher relative growth rate. Similar result was report by Azarpour et al. [24]. Further higher relative growth rate with nitrogen (80 kg/ha) might be due to timely and adequate amount of nitrogen supplied during initial crop growth period. Similar result was reported by Sathiya and Ramesh [25].

3.2 Post-Harvest Observation

3.2.1 Panicle length (cm)

The data revealed that a significantly higher panicle length (30.1 cm) was recorded in treatment 3 [Chakhao Poireiton + Nitrogen (80 kg/ha)]. However, the treatment 2 [Chakhao Poireiton + Nitrogen (70 kg/ha)] and treatment 1 [Chakhao Poireiton + Nitrogen (60 kg/ha)] were found statistically at par with treatment 3 [Chakhao Poireiton + Nitrogen (80 kg/ha)] (Table 2). The significant and higher panicle length was observed with the variety Chakhao Poireiton might due to genetic characters of the varieties primarily influenced by the heredity. Similar result was reported by Diaz et al. [26]. Further significant and higher panicle length with nitrogen (80 kg/ha) might be due to higher nitrogen application influenced better growth characters which ultimately resulted in higher production and translocation of photosynthates towards panicle. Similar result was reported by Dahi and Singh [27].

3.2.2 Number of grains/panicle

The data revealed that a significantly maximum number of grains/panicle (153.60) was recorded in treatment 2 with application of [Chakhao Poireiton + Nitrogen (70 kg/ha)]. However, the treatment 1 [Chakhao Poireiton + Nitrogen (60 kg/ha)] and treatment 3 [Chakhao Poireiton + Nitrogen (80 kg/ha)] were found statistically at par with treatment 2 [Chakhao Poireiton + Nitrogen (70 kg/ha)] (Table 2). The significant and higher number of grains/panicle was observed with the variety Chakhao Poireiton might be due to their genetic makeup and variation in photosynthetic assimilate accumulation. Similar result was reported by Chamely et al. [28]. Further significantly higher number of grains/panicle was observed with Nitrogen (80 kg/ha) might be due to high nitrogen level, greater assimilation of photosynthates resulting in higher number of filled grains. Similar result was reported by Uddin et al. [29].

3.2.3 Test weight (g)

The data revealed that a significantly higher Test Weight (24.01 g) was observed in treatment 3 with application of [Chakhao Poireiton + Nitrogen (80 Kg/ha)]. However, the treatment 1 [Chakhao Poireiton + Nitrogen (60 Kg/ha)] and treatment 6 [Chakhao Amubi + Nitrogen (80 Kg/ha)] were found statistically at par with treatment 3 [Chakhao Poireiton + Nitrogen (80 Kg/ha)] (Table 2). The significant and higher test weight was observed with the variety Chakhao poireiton might be due to genetic character and least influenced by environment, resulted higher test weight. Similar result was reported by Saha et al., [30]. Further significant and higher test weight was observed with Nitrogen (80 kg/ha) might be due to the adequate supply of nitrogen, probably favoured the proper cellular activities during panicle formation and development which led to increase higher test weight. Similar result was reported by Aparna et al. [31].

3.2.4 Grain yield (t/ha)

The data revealed that a significantly higher grain yield (5.67 t/ha) was recorded in treatment 3 [Chakhao Poireiton + Nitrogen (80 Kg/ha)]. However, the treatment 2 [Chakhao Poireiton + Nitrogen (70 Kg/ha)] and treatment 1 [Chakhao Poireiton + Nitrogen (60 Kg/ha)] were found statistically at par with treatment 3 [Chakhao Poireiton + Nitrogen (80 Kg/ha)] (Table 2). The significant and higher grain yield was observed with the variety Chakhao Poireiton might be due to higher number of effective tillers attributed to higher affinity of this variety and yield contributes associate with favourable weather condition followed by differential ability of cultivars and photoassimilate, which resulted in the higher grain yield. Similar result was reported by Anil and Siddi [32]. Further significantly higher grain yield was observed with the application of nitrogen (80 kg/ha) might due to the availability more water enhanced nutrient availability which improved nitrogen and other macro and micro-elements absorption enhancing the production. Similar result was reported by Bhiah and Aljbori [33].

3.2.5 Straw yield (t/ha)

The data revealed that a significantly higher straw yield (11.27 t/ha) was observed and recorded in treatment 3 with the application of [Chakhao Poireiton + Nitrogen (80 Kg/ha)]. However, the application of [Chakhao Poireiton + Nitrogen (70 Kg/ha)] was found statistically at par with the application of [Chakhao Poireiton + Nitrogen (80 Kg/ha)] (Table 2). The significant and higher straw yield was observed with the variety Chakhao Poireiton might be due the production of more tillers and high accumulation of dry matter, resulted increased in straw yield. Similar result was reported by Srimathi and Subramanian [34]. Further significantly higher straw yield was observed with nitrogen (80 Kg/ha) might be due to nitrogen levels improved vegetative growth and increase in the chlorophyll concentration in leaf of plants. Similar result was reported by Biswas et al. [35].

3.2.6 Harvest index (%)

The highest harvest index (34.53) was found in treatment 3 [Chakhao Poireiton + nitrogen (80 kg/ha)], though it was non-significant (Table 2).

Table 1. Response of nitrogen on growth of black rice varieties

		100 DAT			80-100DAT	
S. No.	**Treatment**	**Plant Height (cm)**	**Number of tillers/hill**	**Plant dry weight (g/hill)**	**Crop growth rate (g/ m^2/ day)**	**Relative growth rate (g/ g/ day)**
1.	Chakhao Poireiton + Nitrogen 60 kg/ha	140.90	9.77	31.77	12.11	0.0128
2.	Chakhao Poireiton + Nitrogen 70 kg/ha	141.40	11.97	31.93	13.11	0.0138
3.	Chakhao Poireiton + Nitrogen 80 kg/ha	142.53	13.97	32.49	12.39	0.0128
4.	Chakhao Amubi + Nitrogen 60 kg/ha	138.13	9.57	30.68	11.80	0.0127
5.	Chakhao Amubi + Nitrogen 70 kg/ha	139.03	10.03	30.33	11.43	0.0136
6.	Chakhao Amubi + Nitrogen 80 kg/ha	139.43	9.83	29.85	11.18	0.0138
7.	Chakhao Angangba + Nitrogen 60 kg/ha	136.27	11.67	29.67	12.21	0.0147
8.	Chakhao Angangba + Nitrogen 70kg/ha	137.57	9.67	28.97	11.89	0.0119
9.	Chakhao Angangba + Nitrogen 80kg/ha	138.43	11.73	29.40	13.50	0.0169
	F-test	S	S	S	S	S
	SEm(±)	0.74	0.82	0.30	0.65	0.0008
	CD (p=0.05)	1.56	1.74	0.64	1.38	0.0017

Table 2. Response of nitrogen on yield and yield attributes of black rice varieties

S. No.	**Treatments**	**Panicle length (cm)**	**Number of grains/panicle**	**Test weight (g)**	**Grain yield (t/ha)**	**Straw yield (t/ha)**	**Harvest index (%)**
1.	Chakhao Poireiton + Nitrogen 60 kg/ha	29.80	150.13	23.12	5.17	9.80	33.47
2.	Chakhao Poireiton + Nitrogen 70 kg/ha	29.93	153.47	22.53	5.13	10.20	33.46
3.	Chakhao Poireiton + Nitrogen 80 kg/ha	30.1	153.60	24.01	5.67	11.27	34.53
4.	Chakhao Amubi + Nitrogen 60 kg/ha	28.73	133.00	22.03	4.50	8.83	33.75
5.	Chakhao Amubi + Nitrogen 70 kg/ha	28.90	131.53	21.80	4.90	9.33	34.43
6.	Chakhao Amubi + Nitrogen 80 kg/ha	28.53	134.60	23.20	5.00	10.80	31.64
7.	Chakhao Angangba + Nitrogen 60 kg/ha	28.27	135.47	21.19	3.50	9.17	27.62
8.	Chakhao Angangba + Nitrogen 70kg/ha	28.13	134.80	21.20	3.33	9.83	25.30
9.	Chakhao Angangba + Nitrogen 80kg/ha	28.17	135.40	22.70	3.67	10.07	26.71
	F-test	S	S	S	S	S	NS
	SEm(±)	0.18	1.06	0.58	0.31	0.46	1.72
	CD (p=0.05)	0.39	2.25	1.24	0.66	0.97	-

Table 3. Response of nitrogen on yield and yield attributes on post-harvest yield of Black rice varieties

S. No.	Treatment combinations	Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	B:C ratio
1.	Chakhao Poireiton + Nitrogen 60 kg/ha	49110	216600	167490	3.16
2.	Chakhao Poireiton + Nitrogen 70kg/ha	49190	215400	166210	3.05
3.	Chakhao Poireiton + Nitrogen 80kg/ha	49270	238070	189800	3.23
4.	Chakhao Amubi + Nitrogen 60 kg/ha	49110	188830	140120	2.35
5.	Chakhao Amubi + Nitrogen 70 kg/ha	49190	205330	156540	2.75
6.	Chakhao Amubi + Nitrogen 80 kg/ha	49270	210800	161930	2.91
7.	Chakhao Angangba + Nitrogen 60 kg/ha	49110	149170	100460	2.04
8.	Chakhao Angangba + Nitrogen 70 kg/ha	49190	143030	94240	1.91
9.	Chakhao Angangba + Nitrogen 80 kg/ha	49270	156870	108000	2.19

3.2.7 Economics

The result showed that [Table 3] maximum gross return (2,38,070.00 INR/ha), net return (1,89,800.00 INR/ha) and B:C ratio (3.23) was recorded in treatment 3 with application of Chakhao Poireiton + Nitrogen 80 kg/ha (Table 2). Net returns and benefit cost ratio (3.23) was recorded with the variety Chakhao Poireiton may be due to its superiority than the rest of the varieties, therefore increased in grain yield, resulted higher benefit cost ratio [36]. Further, higher net return was found with application nitrogen (80 kg/ha) might be due to variation in levels of nitrogen monitoring the major inputs, which ultimately increases economic yield with higher net return. Similar result was reported by Mishra et al. [37].

4. CONCLUSION

Based on above findings, it can be concluded that the use of various levels of nitrogen improved the growth parameters and yield attributes of Black rice varieties. Maximum gross return, net return and benefit cost-ratio was recorded with application of Chakhao Poireiton + Nitrogen 80 kg/ha.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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