



Original Research

Integrated Effect of Vermicompost and Inorganic Fertilizers on the Yield Performance of Black Rice in Aman Season

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Abstract

Black rice, a pigmented grain valued for antioxidant activity and functional-food potential, requires locally validated nutrient recommendations for Bangladesh. Therefore, a field trial was undertaken at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh, from July to December 2024, to assess varietal performance and nutrient-management effects on black rice productivity in the *T. aman* season. The study used a randomized complete block design with three replications. Treatments comprised Black rice (Japan) (V_1) and Black rice (Indonesia) (V_2), combined with six nutrient regimes: no fertilizer or vermicompost (N_1); the recommended inorganic fertilizer dose (N_2); vermicompost at 5.0 t ha^{-1} (N_3); 75% of the recommended fertilizer dose plus 1.25 t ha^{-1} vermicompost (N_4); 50% of the recommended dose plus 2.5 t ha^{-1} vermicompost (N_5); and 25% of the recommended dose plus 3.75 t ha^{-1} vermicompost (N_6). Both factors significantly affected most yield-related traits. V_1 exceeded V_2 , recording grain yield of 3.75 t ha^{-1} , straw yield of 5.72 t ha^{-1} , biological yield of 9.48 t ha^{-1} , and a harvest index of 39.71%. N_2 resulted in maximum plant height (110.58 cm), effective tillers hill⁻¹ (11.59), panicle length (23.14 cm), grains panicle⁻¹ (87.29), 1000-grain weight (28.07 g), grain yield (4.10 t ha^{-1}), straw yield (6.71 t ha^{-1}), and biological yield (10.82 t ha^{-1}). The V_1N_2 combination produced the highest grain, straw, and biological yields of 4.21, 6.79, and 11.00 t ha^{-1} , respectively, whereas V_1N_4 recorded the highest number of effective tillers (11.83 plant⁻¹). Although V_1N_4 was also satisfactory, V_1 with N_2 was the best option for maximizing yield under the present experimental conditions.

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Statement of Sustainability: This study acknowledges that the integrated application of vermicompost and inorganic fertilizers can contribute to sustainable black rice production by improving productivity, supporting efficient nutrient management, and reducing reliance on inorganic fertilizers, thereby promoting long-term agricultural sustainability and environmental protection. Such an integrated nutrient management approach can also enhance the utilization of available organic resources, maintain soil fertility, and support balanced nutrient supply for crop growth. The findings therefore highlight the potential of combining organic and inorganic nutrient sources as a practical strategy for maintaining productivity while promoting more sustainable and environmentally responsible rice production systems.

1. Introduction

One of the world's oldest crops, rice (*Oryza sativa*), has been domesticated for more than 8,000 years in the Yangtze River basin of China (Asha et al., 2025). Based on archeological discoveries, rice traveled via trade routes and migration to India, Southeast Asia,

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and subsequently Africa and Europe (Spengler et al., 2021). It grows as an annual grass and is best suited to warm, water-rich environments (Mia and Salam, 2024). Starch, proteins, and vital micronutrients can be found in rice grains.

Over half of the world's population relies on rice as a staple diet, and it is especially important in Asia. Rice is the primary source of daily calories for nations like Bangladesh, China, India, and Indonesia. Around 70% of Bangladesh's total caloric intake comes from rice, which gives millions of farmers employment and ensures food security (Fiza et al., 2024). It is processed into goods like rice flour, snacks, and drinks in addition to being directly ingested.

Over the past few decades, the world's rice output has continuously expanded to satisfy the growing demand from the growing population. According to the FAO (2021), the world's rice production in 2020 was around 782 million tons, whereas the world's consumption was about 790 million tons. Due to dietary changes, urbanization, and population growth, rice consumption is expected to increase throughout Asia and Africa. According to BBS (2022), the yearly demand for rice in Bangladesh is between 37 and 38 million tons, while the production is about 35 million tons.

Aman (monsoon), *Boro* (dry season irrigated rice), and *Aus* (pre-monsoon) are the three main seasons in Bangladesh when rice is grown. The Rajshahi, Rangpur, Khulna, Barishal, and Dhaka divisions are important rice-producing areas. *Aman* rice is largely dependent on rainfall, but *Boro* rice has the maximum output because of controlled irrigation (Mia et al., 2024a). In Bangladesh, black rice is mostly grown during the *aman* season due to its high nutritional value and antioxidant content. To increase productivity, farmers combine contemporary methods such as balanced fertilizing and line planting with traditional farming methods (Chowdhury et al., 2024).

Climate change, flooding, salinity, pest infestations, and insufficient utilization of contemporary inputs are some of the problems Bangladesh's rice industry faces. Improved high-yielding cultivars, integrated pest management, contemporary irrigation techniques, and the application of both organic and inorganic fertilizers are some of the current methods used to boost the production of rice (Jamal et al., 2023; Jesia et al., 2025). Vermicompost, which is made by earthworms from organic waste, boosts soil fertility, aeration, and water retention. Based on studies, adding vermicompost to rice fields increases root growth, nutrient uptake, and, ultimately, rice yield while minimizing environmental pollution (Mia et al., 2024b).

Important nutrients like potassium, phosphorus, and nitrogen are supplied in easily accessible forms by inorganic fertilizers. When utilized in the right amounts and in conjunction with organic amendments, they greatly improve rice productivity and grain quality (Islam et al., 2024).

According to research, black rice growth and yield are enhanced when vermicompost and inorganic fertilizers are combined during the *aman* season as opposed to using either input alone. Rice plants' stress tolerance, nutrient availability, and soil health are all improved by this integrated nutrient management (Imran-Hossain-Sohag et al., 2025; Islam et al., 2025). Studies on ordinary or aromatic rice have been the most prevalent in Bangladesh during the *aman* season, although studies specifically on black rice are still rare and typically employ non-*aman* circumstances or other organic sources. Thus, it is appropriate to conduct a field study on the combined impact of vermicompost and inorganic fertilizers on black rice during the *aman* season.

However, despite the growing interest in black rice and integrated nutrient management, information on the response of black rice varieties to different combinations of vermicompost and inorganic fertilizers under *T. Aman* conditions in Bangladesh remains limited. Previous studies have mainly focused on conventional or aromatic rice, or have evaluated nutrient management under different environmental conditions and with other organic amendments. Therefore, comparative information on the performance of different black rice varieties and their response to integrated nutrient management during the *T. Aman* season is still insufficient. Addressing this gap is important for identifying suitable varieties and nutrient-management practices for improving black rice productivity under the agroecological conditions of Bangladesh.

Such a study would assist in determining whether vermicompost may partially replace inorganic fertilizer while preserving or enhancing black rice growth, yield characteristics, and grain production in Bangladesh's wet season. In order to accomplish the following goals, the current study was conducted: to assess the varietal performances of black rice (Japan, Indonesia) varieties in *T. aman* season; to assess the yield performance of black rice varieties under the INM system in *T. aman* season; and to observe the combined effect of varieties and INM on the yield characters and yield performance of black rice varieties in *T. aman* season.

2. Materials and Methods

2.1. Experimental Site

The experimental site is located at 24°25' N latitude and 90°50' E longitude at an elevation of 18 m above the mean sea level. The experimental area is characterized by non-calcareous dark grey floodplain soil belonging to the Sonatola soil series under the Old Brahmaputra Floodplain, agro-ecological zone 9 (UNDP and FAO, 1988).



2.2. Experimental Soil

The experimental field's soil had a pH of 6.5, was relatively neutral, and had modest levels of fertility and organic matter. Under the Old Brahmaputra Alluvial Tract, the experimental land's soil is part of the Sonatola series of non-calcareous dark gray floodplain soil. The texture of the terrain was silt loam and it was fairly high.

2.3. Experimental Design and Layout

A Randomized Complete Block Design (RCBD) with three replications was used to set up the experiment. There were 36 plots in all, each measuring 5 m².

2.4. Experimental Treatments

The experimental treatment consisted of two factors. They are as follows: Factor A: Variety (2) Black rice (Japan) (V1), Black rice (Indonesia) (V2). Factor B: Integrated Nutrient Management (6) Control (no application of Vermicompost and fertilizer) (N1), Recommended dose (kg ha⁻¹) of inorganic fertilizer (N2) [Urea: 220, TSP: 100, MoP: 80, Gypsum: 60, Borax: 10], Vermicompost @ 5.0 t ha⁻¹ (N3), 25% less than recommended dose of inorganic fertilizer + Vermicompost @ 1.25 t ha⁻¹ (N4), 50% less than recommended dose of inorganic fertilizer + Vermicompost @ 2.5 t ha⁻¹ (N5), 75% less than recommended dose of inorganic fertilizer + Vermicompost @ 3.75 t ha⁻¹ (N6).

2.5. Crop Husbandry

Seeds of the test cultivar were collected from North Bengal Agro, Rajapur, Dhamrai, Dhaka. Using a specific gravity method, healthy seeds from the cultivars that were gathered were chosen. After that, seeds were submerged in water in a bucket for a whole day. These were then promptly removed from the water and stored in gunny bags. After 48 hours, the seeds begin to sprout and are ready to be sown. To raise seedlings, a plot of land was chosen. On July 2, 2024, the sprouting seeds were evenly distributed in a well-prepared nursery bed after the land had been puddled well with a tractor and leveled with a ladder. The healthy seedlings in the nursery bed were raised with careful attention. The nursery bed's weeds were pulled as needed. The field was set up on August 1st, 2024. After using a tractor-drawn plow to till the field, laddering was done. Following final land preparation, the field's layout was created, and each plot's weeds and stubble were cleared. In order to guaranty ideal development and production during the *Aman* season, fertilizer treatment for both Black rice (Japan) and Black rice (Indonesia) in the current study adhered to BRRI's suggested methods. 220 kg of urea, 100 kg of triple super phosphate (TSP), 80 kg of muriate of potash (MoP), 60 kg of gypsum, and 10 kg of borax were used per hectare as fertilizers. While all other fertilizers were applied during final land preparation, nitrogen was applied in three equal splits: as a basal dose, at the active tillering stage, and at the panicle initiation stage. One day before the plants were uprooted, water was applied to the nursery bed to make it damp. On August 7, 2024, thirty-day-old seedlings were carefully removed from the nursery bed. Healthy and comparable-sized seedlings were chosen for transplantation, and the uprooted seedlings were promptly moved to the main field. On August 8, 2024, seedlings were moved into the prepared puddle field at a pace of three seedlings per hill, with row and hill distances of 25 cm and 15 cm, respectively.

2.6. Data Collection Parameters

Data of yield and yield contributing characters were recorded from five randomly selected sample plants from each plot on the following parameters: Plant height (cm), Number of total tillers hill⁻¹, Number of effective tillers hill⁻¹, Number of non-effective tillers hill⁻¹, Panicle length, Number of grains panicle⁻¹, Number of sterile spikelets panicle⁻¹, Weight of 1000 grain, Grain yield (t ha⁻¹), Straw yield (t ha⁻¹), Biological yield (t ha⁻¹), Harvest index (%)

2.7. Grain and Straw Yield (t ha⁻¹):

Grains and straw obtained from each unit plot, including those obtained from the central 1 m² area of the respective plot, were sun-dried and weighed carefully. The total grain and straw weights were recorded as grain yield plot-1 and straw yield plot-1, respectively, and subsequently converted to t ha⁻¹.

2.8. Harvest Index (%)

It indicates the ratio of economic yield (grain yield) to biological yield and was calculated by the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100 \quad (1)$$

2.9. Statistical Analysis

Analysis of variance (ANOVA) was performed using Statistix 10 statistical software. To determine statistically significant differences among treatment means, the Least Significant Difference (LSD) test was performed at the 5% level of significance ($p < 0.05$).



The assumptions of normality and homogeneity of variance were verified before conducting the analysis to ensure the validity of the ANOVA. Duncan's Multiple Range Test (DMRT), as described by Gomez and Gomez (1984), was used to compare treatment means and identify significant differences among them.

3. Results and Discussion

3.1. Yield Contributing Characters and Yield

3.1.1. Effect of Variety

Variety had no discernible impact on plant height (Table 1). In terms of numbers, V1 yielded somewhat taller plants (108.44 cm) than V2 (108.18 cm), but the difference was negligible and not statistically significant. This suggests that under the experimental conditions, both kinds displayed nearly identical plant height. Plant height varied between the two cultivars since it is a varietal trait and a genetic component of the cultivar. The findings align with those of Islam et al. (2024), who noted that plant height was statistically comparable throughout the variety. There were notable differences in the total number of tillers per hill among the kinds (Table 1). In comparison to V2 (12.35), V1 generated more total tillers per hill⁻¹ (13.19). This implies that, in the experimental setting, V1 was more adept at tillering than V2. Azme et al. (2016) discovered that the number of total tillers varied significantly between the varieties. Variety did not significantly affect the number of effective tillers per hill (Table 1). 10.85 effective tillers hill⁻¹ were produced by V1, and 10.74 effective tillers hill⁻¹ by V2. The two kinds' ability to generate fruitful tillers was nearly identical, as seen by their slight differences. According to Humaira et al. (2025), a similar pattern of tillering habits with various rice types was recorded by the total number of tillers. There were substantial differences in the number of non-effective tillers per hill among the types (Table 1). The number of non-effective tillers hill⁻¹ was larger in V1 (2.33) than in V2 (1.61). Despite having more tillers overall, some of V1's tillers were still inefficient. According to Chowdhury et al. (2016), different types had statistically equivalent numbers of non-effective tillers. Variety had a substantial impact on panicle length (Table 1). Compared to V2 (22.19 cm), V1 produced panicles that were longer (22.68 cm). When combined with more grains per panicle and efficient tillers, longer panicles may enhance yield potential. This outcome was consistent with Sheik et al. (2017)'s findings that panicle length and variety are significantly correlated. Variety had no discernible effect on the amount of grains per panicle (Table 1). Though the difference was not statistically significant, V2 produced slightly more grains panicle⁻¹ (78.87) than V1 (78.74). As a result, the ability of both types to produce grain per panicle was comparable.

Variety had no discernible effect on the number of sterile spikelets panicle⁻¹ (Table 1). V1 generated 10.32 sterile spikelets per panicle, whereas V2 generated 9.69. Even though the difference was not statistically significant, the lower value in V2 suggests a little numerical advantage. Ullah et al. (2016) reported comparable results, finding that the quantity of sterile spikelets panicle⁻¹ was statistically identical due to varietal characteristics. Variety had no discernible impact on the 1000-grain weight (Table 1). 27.88 g was recorded by V1 and 27.84 g by V2. The cultivars' grain yields varied significantly from one another. Compared to V2 (3.44 t ha⁻¹), V1 produced greater grain (3.75 t ha⁻¹) (Figure 1). The grain output of V1 (Black rice Japan) is influenced by a number of factors, including a greater 1000-grain weight, a longer panicle length, a slightly higher number of effective tillers, and a superior harvest index. Soheli et al. (2020) demonstrated similar results in aman rice variants.

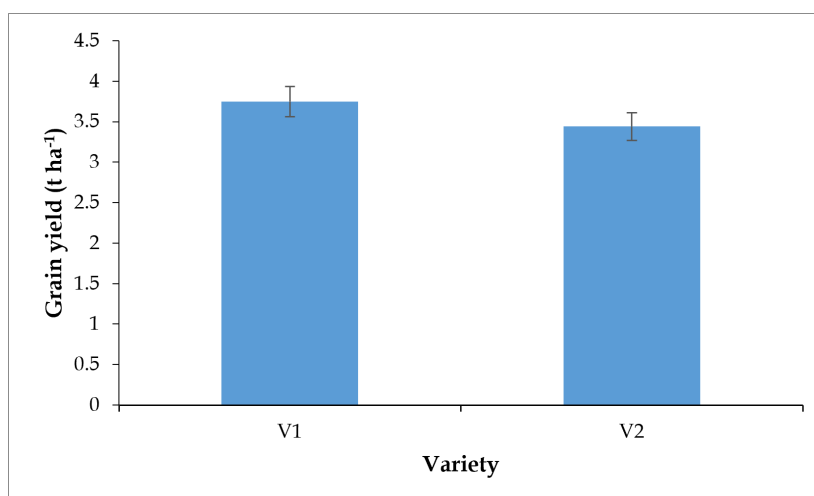


Figure 1. Effect of variety on grain yield. Bar represents standard error of the mean V1 = Black rice (Japan), V2 = Black rice (Indonesia).

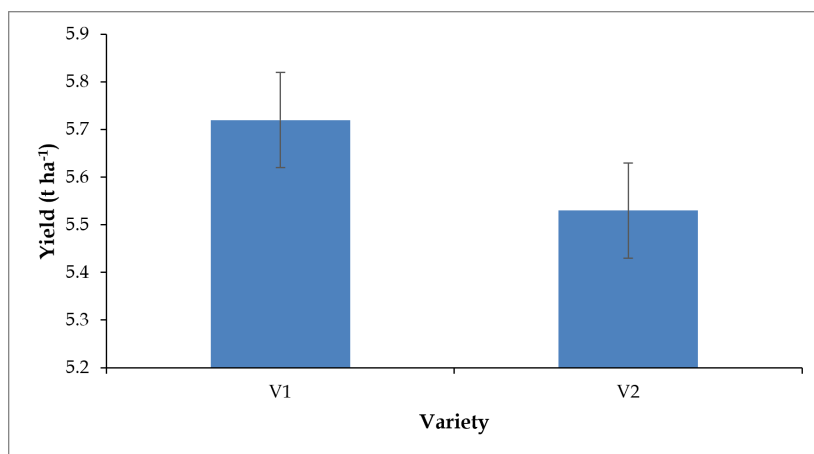


Figure 2. Effect of variety on straw yield. Bar represents standard error of the mean V1 = Black rice (Japan), V2 = Black rice (Indonesia).

Variety had a major impact on straw yield. Compared to V2 (5.53 t ha⁻¹), V1 yielded more straw (5.72 t ha⁻¹) (Figure 2). Significant differences across aman rice cultivars were also noted by Ferdous et al. (2016).

Variety has a substantial impact on biological yield (Table 1). Biological yield was higher in V1 (9.48 t ha⁻¹) than in V2 (8.98 t ha⁻¹). Because V1 (Black rice Japan) produced more grain and straw, it had a greater biological yield. Varieties differed in their biological yield, according to Sheik et al. (2017). Variety had a considerable impact on the harvest index (Table 1). V1 harvest index (39.71%) was greater than V2 (38.44%). Better biological yield partitioning into grain yield is indicated by a higher harvest index of V1. Rahman et al. (2020) discovered that the harvest index varied significantly between types.

Table 1. Effect of variety on yield contributing characters of black rice.

Variety	Plant height (cm)	Number of total tillers hill ⁻¹	Number of effective tillers hill ⁻¹	Number of non-effective tillers hill ⁻¹	Panicle length (cm)	Number of grains panicle ⁻¹	Number of sterile spikelets	1000-grain weight (g)	Biological yield (t ha ⁻¹)	Harvest index (%)
V ₁	108.44	13.19a	10.85	2.33a	22.68a	78.74	10.32	27.88	9.48a	39.71a
V ₂	108.18	12.35b	10.74	1.61b	22.19b	78.87	9.69	27.84	8.98b	38.44b
LSD	1.33	0.62	0.29	0.66	0.44	2.71	0.67	0.26	0.13	0.83
(0.05) Level of significance	NS	**	NS	**	**	NS	NS	NS	**	**
CV (%)	5.78	7.09	3.99	8.71	2.85	4.99	9.80	3.35	2.16	3.09

In a column figures having common letter(s) do not differ significantly as per DMRT. ** = Significant at 1% level of probability, NS = Not significant, V1 = Black rice (Japan), V2 = Black rice (Indonesia).

3.1.2. Effect of Integrated Nutrient Management

Plant height was significantly impacted by the treatment (Table 2). N2 (110.58 cm) had the tallest plant, which was statistically comparable to N4 (109.42 cm) and N5 (108.41 cm). In N1, the shortest plant was measured at 106.42 cm. The greater plant height under N2 suggests that this treatment offered a more conducive environment for vegetative growth. These findings are in line with those of Rahman et al. (2020), who observed a comparable rise in plant height in rice under integrated nutrient management techniques. The number of total tillers hill⁻¹ was significantly affected by treatment (Table 2). N1 (13.41) had the greatest total tillers hill⁻¹, which was statistically comparable to N3 (13.16) and N2 (12.97). N5 had the lowest number (11.80). Even though N1 produced the most total tillers, many of those tillers were ineffective, hence a high total tiller count did not always translate into the maximum grain yield. According to Abdullah-Al-Nomuna et al. (2020), integrated nutrient management greatly similarizes the total number of tillers. The number of effective tillers hill⁻¹ was significantly impacted by treatment (Table 2). N2 had the most effective tillers per hill⁻¹ (11.59), which was statistically comparable to N4 (11.33). N1 had the lowest value (10.27). Grain yield was positively impacted by the increased number of effective tillers under N2 and N4. These findings align with those of Farhat et al. (2023). The number of ineffective tillers hill⁻¹ was considerably impacted by treatment (Table 2). N1 had the greatest number of ineffective tillers per hill⁻¹ (3.14), followed by N3 (2.80). N5 had the lowest number (1.09), which was statistically comparable to N4 (1.19) and N2 (1.38). Better tiller productivity and assimilate utilization are indicated by fewer ineffective tillers, which is ideal.



Similar findings were also reported by Hossain et al. (2024), who concluded that the number of ineffective tillers was statistically comparable using various integrated nutrition management techniques. These results are in conformity with the findings of Farhat et al. (2023). Panicle length was considerably impacted by treatment (Table 2). N2 has the longest panicle (23.14 cm), followed by N4 (22.93 cm). N1 has the shortest panicle (21.61 cm). The longer panicles under N2 show that this therapy has a positive impact on reproductive growth. In the study by Hossain et al. (2024), panicle length was statistically comparable across various integrated nutrient management strategies. The number of sterile spikelets in panicle⁻¹ was significantly affected by treatment (Table 2). N1 (11.56) had the most sterile spikelets, with N3 (10.90) and N6 (10.61) following closely behind. N2 (8.95) and N5 (9.40) were statistically comparable to N4 (8.64), which had the lowest number (Table 2). Grain filling and yield were improved under N2 and N due to decreased sterility. This result was consistent with that of Farhat et al. (2023), who found a statistically similar number of sterile sterile spikelets per panicle⁻¹. 1000-grain weight was substantially impacted by treatment (Table 2). N2 had the greatest 1000-grain weight (28.07 g), which was statistically comparable to N5 (28.04 g), N3, N4 (27.86 g), and N1. N6 (27.60 g) had the lowest value. Compared to other yield components, 1000-grain weight was less variable, as evidenced by the narrow range among treatments. Salam et al. (2022) reported that experimental settings for integrated nutrient management eventually increase the weight of 1000 grains. The treatment greatly affected grain yield. Grain yield was highest in N2 (4.10 t ha⁻¹) and lowest in N4 (3.78 t ha⁻¹). N1 produced the least amount of grain (3.19 t ha⁻¹) (Figure 3). N2 superiority was associated with greater plant height, effective tillers hill⁻¹, panicle length, grains panicle, and 1000-grain weight, as well as somewhat lower spikelet sterility. Naher et al. (2017), also reported similar results where integrated nutrient management influenced grain yield.

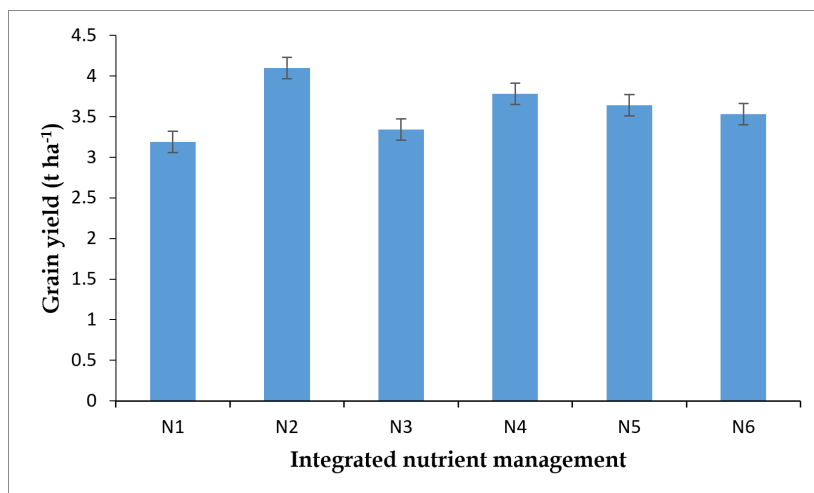


Figure 3. Effect of integrated nutrient management on grain yield. Bar represents standard error of the mean (N1 = Control (no application of Vermicompost and fertilizer), N2 = Recommended dose of inorganic fertilizer, N3 = Vermicompost @ 5.0 t ha⁻¹, N4 = 25% less than recommended dose of inorganic fertilizer + Vermicompost @ 1.25 t ha⁻¹, N5 = 50% less than recommended dose of inorganic fertilizer + Vermicompost @ 2.5 t ha⁻¹, N6 = 75% less than recommended dose of inorganic fertilizer + Vermicompost @ 3.75 t ha⁻¹).

Straw yield was greatly impacted by the treatment. N2 had the largest straw yield (6.71 t ha⁻¹), followed by N4 (6.15 t ha⁻¹). N1 had the lowest straw production (4.68 t ha⁻¹) (Figure 4). Increased biomass production under N2 is indicated by the higher straw yield. Similar findings were reported by Ashraf et al. (2021), who noted that straw yield varied considerably depending on integrated nutrition management. Harvest index was considerably impacted by treatment (Table 2). N1 had the greatest harvest index (40.52%), which was followed by N6 (39.39%), N5 (39.35%), and N3 (39.18%). The harvest index for N2 was the lowest (37.92%). Because N2 also produced the highest biological and straw yields, its harvest index was lower even though it produced the maximum grain yield. Similar findings were reported by Salam et al. (2022), who noted that there were substantial differences in the harvest index between integrated nutrition management.

3.1.3. Interaction Effect of Variety and Integrated Nutrient Management

Plant height was greatly impacted by the combination of variety and integrated nutrition management (Table 3). V1N2 had the tallest plant (110.83 cm), followed by V2N2 (110.33 cm). V2N1 had the lowest plant height. The findings show that N2 increased plant height in both types, although V1 showed a marginally higher response. This outcome is in line with the findings of Islam et al. (2024), who found that integrated nutrition management and plant height were statically similar across the kinds. For total tillers hill⁻¹, the interaction impact was substantial (Table 3). V1N1 had the highest total number of tillers hill⁻¹ (14.67), followed by V1N3 (14.33). V2N5 had the lowest number (11.38). The findings demonstrated that there were significant differences in the tillering



response between the variety-treatment combinations. The findings of Ashraf et al. (2021), who documented the variance in tiller production as a result of variety interaction and integrated nutrient management, are consistent with these results. Effective tillers hill^{-1} were significantly influenced by the combination of variety and integrated nutrient management (Table 3). V1N4 had the most effective tillers per hill^{-1} (11.83), followed by V2N2 (11.69) and V1N2 (11.50). V1N1 has the lowest number (10.16). The outcome shows that N2 and N4 combinations improved the conversion of total tillers into productive tillers. Sadik et al. (2025) found that tillering tendencies varied depending on the variety. For non-effective tillers hill^{-1} , the interaction impact was significant (Table 3). V1N1 had the greatest number of non-effective tillers per hill^{-1} (4.50), followed by V1N3 (4.05). V1N4 had the lowest value (0.66).

The outcome demonstrates that whereas N4 successfully decreased the generation of non-effective tillers, V1 produced more ineffective tillers under N1 and N3. Mahato et al. (2014) reported similar results, stating that the interplay between cultivars and integrated nutrition management had a substantial impact on the number of non-effective tillers. Sadik et al. (2025) found that tillering tendencies varied depending on the variety. Panicle length showed a significant interaction between variety and integrated nutrient management (Table 3). V1N2 (23.21 cm) had the longest panicle, followed by V2N2 (23.08 cm), V2N4 (22.99 cm), and V1N4 (22.87 cm). V2N1 has the shortest panicle, measuring 20.62 cm. The outcome indicates that both kinds' panicle length was enhanced by N2. According to Siddika et al. (2014), there was statistical similarity between the interaction between varieties and integrated nutrition management. There was a substantial interaction impact on grains panicle $^{-1}$ (Table 3). V2N2 (88.73) had the highest number of grains per panicle, followed by V1N2 (85.85), V1N4 (85.26), and V2N4 (84.90). V1N3 contained the lowest number (69.33). The outcome shows that N2 was quite successful in raising the quantity of grains in both types, especially in V2.

According to Hossain et al. (2024), the interaction between varieties and integrated nutrient management results in a more favorable environment, which raises the quantity of grains per panicle. For sterile spikelets panicle $^{-1}$, the interaction effect was statistically significant (Table 3). V1N1 had the greatest number of sterile spikelets (11.61), with V2N1 coming in second (11.52). V2N4 (7.91) had the lowest number, followed by V2N5 (8.51) and V2N2. This suggests that V2 under N4 had higher reproductive efficiency and the lowest spikelet sterility. According to Abdullah-Al-Numana et al. (2020), interaction between cultivars and integrated nutrient management resulted in a statically equal amount of sterile spikelets per panicle. 1000-grain weight was significantly affected by the combination of diversity and integrated nutrient management (Table 3). V1 N5 (28.13 g) had the highest value, followed by V2N2 (28.09 g), V1N2 (28.05 g), and V1N3 (27.46 g). The interaction was considerable, but most combinations had relatively little numerical variation. This result was consistent with that of Siddika et al. (2024), who found that in the case of 1000-grain weight, the interaction between varieties and integrated nutrient management was statistically identical. Grain yield was significantly impacted by the relationship between variety and integrated nutrient management. V1N2 had the largest grain yield (4.21 t ha^{-1}), followed by V2N2 (4.00 t ha^{-1}) and V1N4 (3.88 t ha^{-1}). V2N1 had the lowest grain yield (2.96 t ha^{-1}) (Figure 5). According to these findings, N2 was the most productive treatment for both types, and the greatest combination for increasing grain production was V1N2. According to Salam et al. (2022), the interplay between cultivars and integrated nutrition management has a considerable impact on yield components.

Straw yield was significantly impacted by the interaction effect. V1N2 had the maximum straw yield (6.79 t ha^{-1}), which was statistically comparable to V2N2 (6.64 t ha^{-1}). According to Figure 6, V2N1 had the lowest value (4.59 t ha^{-1}). N2 consistently increased straw yield in both kinds, according to the results. According to Abdullah-Al-Nomuna et al. (2020), the interplay between cultivars and integrated nutrient management has no discernible impact on straw yield.

Table 2. Effect of integrated nutrient management on yield contributing characters of black rice.

Integrated nutrient management	Plant height (cm)	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Panicle length (cm)	Number of grains panicle $^{-1}$	Number of sterile spikelets	Biological yield (t ha^{-1})	Harvest index (%)
N ₁	106.42c	13.41a	10.27b	3.14a	21.61c	74.45bc	11.56a	7.87f	40.52a
N ₂	110.58a	12.97a	11.59a	1.38b	23.14a	87.29a	8.95b	10.82a	37.92c
N ₃	107.76bc	13.16a	10.36b	2.80a	22.32bc	72.55c	10.90a	8.53e	39.18abc
N ₄	109.42a-b	12.52ab	11.33a	1.19b	22.93ab	85.08a	8.64b	9.93b	38.09bc
N ₅	108.41a-bc	11.80b	10.70b	1.09b	22.33bc	77.78b	9.40b	9.27c	39.35abc
N ₆	107.30bc	12.77ab	10.53b	2.23ab	22.28bc	75.70bc	10.61a	8.97d	39.39ab
LSD _(0.05)	2.31	1.08	0.51	1.15	0.76	4.70	1.17	0.23	1.44
Level of significance	**	**	**	**	*	**	**	**	**
CV (%)	5.78	7.09	3.99	8.71	2.85	4.99	9.80	2.16	3.09

In a column figures having common letter(s) do not differ significantly as per DMRT. = Significant at 5% level of probability. * = Significant at 1% level of probability, N₁ = Control (no application of Vermicompost and fertilizer), N₂ = Recommended dose of inorganic fertilizer, N₃ = Vermicompost @ 5.0 t ha^{-1} , N₄ = 25% less than recommended dose of inorganic fertilizer + Vermicompost @ 1.25 t ha^{-1} , N₅ = 50% less than recommended dose of inorganic fertilizer + Vermicompost @ 2.5 t ha^{-1} , N₆ = 75% less than recommended dose of inorganic fertilizer + Vermicompost @ 3.75 t ha^{-1} .

Variety and integrated nutrition management had a substantial interaction effect on biological yield (Table 3). V1 N2 had the largest biological production (11.00 t ha^{-1}), with V2N2 coming in second (10.64 t ha^{-1}). V1N1 had the lowest biological yield (7.55

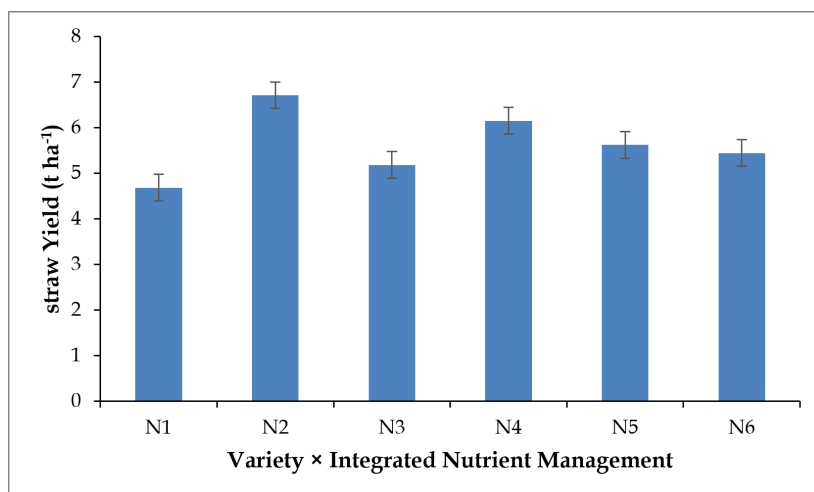


Figure 4. Effect of integrated nutrient management on straw yield. Bar represents standard error of the mean (N1 = Control (no application of Vermicompost and fertilizer), N2 = Recommended dose of inorganic fertilizer, N3 =Vermicompost @ 5.0 t ha⁻¹, N4 = 25% less than recommended dose of inorganic fertilizer + Vermicompost @ 1.25 t ha⁻¹, N5 = 50% less than recommended dose of inorganic fertilizer + Vermicompost @ 2.5 t ha⁻¹, N6 = 75% less than recommended dose of inorganic fertilizer + Vermicompost @ 3.75 t ha⁻¹).

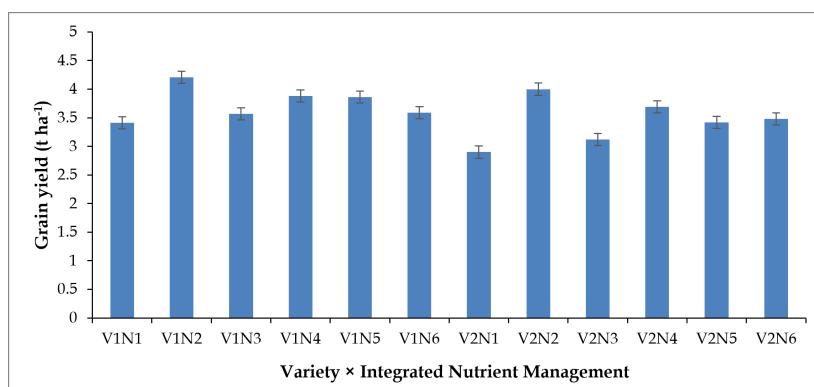


Figure 5. Interaction effect of variety and integrated nutrient management on grain yield. Bar represents standard error of the mean (V1 = Black rice (Japan), V2 = Black rice (Indonesia), N1 = Control (no application of Vermicompost and fertilizer), N2 = Recommended dose of inorganic fertilizer, N3 =Vermicompost @ 5.0 t ha⁻¹, N4 = 25% less than recommended dose of inorganic fertilizer + Vermicompost @ 1.25 t ha⁻¹, N5 = 50% less than recommended dose of inorganic fertilizer + Vermicompost @ 2.5 t ha⁻¹, N6 = 75% less than recommended dose of inorganic fertilizer + Vermicompost @ 3.75 t ha⁻¹).

t ha⁻¹). The outcome demonstrates that the optimal combination for overall biomass output was V1N2. According to Humaira et al. (2025), coordinated nutrition management and variety interaction are crucial for boosting biological yield. The harvest index exhibits significant interaction effect (Table 3). V1N1 had the highest harvest index (41.74%), with V1N3 coming in second (40.69%). V2N2 (37.58%), V2N3 (37.66%), and V2N4 (37.50%) had the lowest values. The outcome shows that a higher harvest index by itself did not guaranty a better grain yield; rather, V1N2 produced the best grain yield because of its high biological yield and improved yield components. According to Farhat et al. (2023), integrated nutrition management and variety interaction have a major impact on the harvest index.

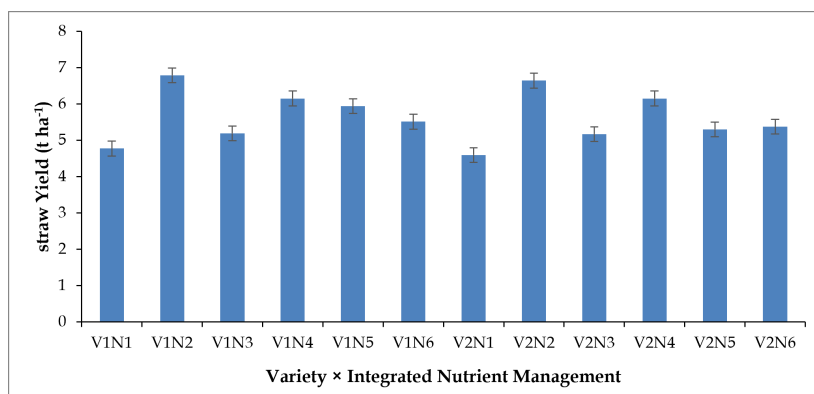


Figure 6. Interaction effect of variety and integrated nutrient management on straw yield. Bar represents standard error of the mean (V1 = Black rice (Japan), V2 = Black rice (Indonesia), N1 = Control (no application of Vermicompost and fertilizer), N2 = Recommended dose of inorganic fertilizer, N3 = Vermicompost @ 5.0 t ha⁻¹, N4 = 25% less than recommended dose of inorganic fertilizer + Vermicompost @ 1.25 t ha⁻¹, N5 = 50% less than recommended dose of inorganic fertilizer + Vermicompost @ 2.5 t ha⁻¹, N6 = 75% less than recommended dose of inorganic fertilizer + Vermicompost @ 3.75 t ha⁻¹).

Table 3. Interaction effect between yield contributing characters of black rice.

Interaction	Plant height (cm)	Number of total tillers hill ⁻¹	Number of effective tillers hill ⁻¹	Number of non-effective tillers hill ⁻¹	Panicle length (cm)	Number of grains panicle ⁻¹	Number of sterile spikelets	1000-grain weight (g)	Biological yield (t ha ⁻¹)	Harvest index (%)
V ₁ N ₁	107.00cd	14.67a	10.16e	4.50a	22.60ab	78.73bcd	11.61a	27.68ab	8.18f	41.74a
V ₁ N ₂	110.83a	13.11bc	11.50abc	1.61cd	23.21a	85.85a	9.22cde	28.05ab	11.00a	38.26c
V ₁ N ₃	107.50bcd	14.33ab	10.28de	4.05ab	22.53ab	69.33f	10.84abc	28.03ab	8.76de	40.69ab
V ₁ N ₄	109.50abc	12.50cd	11.83a	0.66d	22.87ab	85.26ab	9.37bcde	27.97ab	10.03c	38.67bc
V ₁ N ₅	108.50abcd	12.22cd	10.96bcd	1.26cd	22.42ab	78.42cd	10.29abcd	28.13a	9.81c	39.45bc
V ₁ N ₆	107.33bcd	12.33cd	10.40de	1.93cd	22.47ab	74.85def	10.62abc	27.46b	9.10d	39.45bc
V ₂ N ₁	105.83d	12.16cd	10.37de	1.79cd	20.62c	70.16ef	11.52a	27.63ab	7.55g	39.30bc
V ₂ N ₂	110.33ab	12.84bcd	11.69ab	1.15cd	23.08ab	88.73a	8.67de	28.09ab	10.64b	37.58c
V ₂ N ₃	108.01abcd	12.00cd	10.45de	1.55cd	22.10b	75.78def	10.96ab	27.87ab	8.29f	37.66c
V ₂ N ₄	109.33abc	12.55cd	10.84cde	1.72cd	22.99ab	84.90abc	7.91e	27.76ab	9.84c	37.50c
V ₂ N ₅	108.33abcd	11.38d	10.44de	0.93cd	22.24ab	77.13d	8.51e	27.95ab	8.73e	39.25bc
V ₂ N ₆	107.26bcd	13.21abc	10.66de	2.54bc	22.09b	76.55de	10.60abc	27.74ab	8.85de	39.33bc
LSD (0.05)	3.26	1.53	0.73	1.63	1.08	6.65	1.66	0.63	0.33	2.04
Level of significance	**	**	**	**	*	**	**	*	**	**
CV (%)	5.78	7.09	3.99	8.71	2.85	4.99	9.80	3.35	2.16	3.09

In a column figures having common letter(s) do not differ significantly as per DMRT. = Significant at 5% level of probability. * = Significant at 1% level of probability, V1 = Black rice (Japan), V2 = Black rice (Indonesia), N1 = Control (no application of Vermicompost and fertilizer), N2 = Recommended dose of inorganic fertilizer, N3 = Vermicompost @ 5.0 t ha⁻¹, N4 = 25% less than recommended dose of inorganic fertilizer + Vermicompost @ 1.25 t ha⁻¹, N5 = 50% less than recommended dose of inorganic fertilizer + Vermicompost @ 2.5 t ha⁻¹, N6 = 75% less than recommended dose of inorganic fertilizer + Vermicompost @ 3.75 t ha⁻¹.

4. Conclusion

As per the study's findings, black rice growth, yield-contributing traits, and yield were significantly impacted by variety and nutrient management. In terms of grain production, straw yield, biological yield, and harvest index, black rice from Japan performed



better than black rice from Indonesia. Among the nutrient management treatments, the prescribed dose of inorganic fertilizer yielded the highest production and the most advantageous yield features. With the highest grain, straw, and biological yields, V1N2 was the optimal treatment combination. Therefore, under the current experimental conditions, this combination might be the best choice for achieving a larger yield of black rice. To verify the consistency of these results, additional research could be carried out in various settings and times of year.

Author Contributions

Conceptualization: Fahmida Akter, Md. Shafiqul Islam; Data curation: Md. Moshuazzaman, Susmita Rakshit, Sunanda Sarker Proma; Funding acquisition: Fahmida Akter, Md. Shafiqul Islam; Investigation: Md. Moshuazzaman, Md. Liton Mia, Fahmida Akter, Md. Shafiqul Islam; Methodology: Md. Moshuazzaman, Fahmida Akter, Md. Shafiqul Islam; Resources: Jannatun Nahar Jui, Susmita Rakshit, Sujan Kumar Bhowmik; Formal analysis: Md. Moshuazzaman, Susmita Rakshit, Md. Liton Mia; Software: Md. Liton Mia, Sujan Kumar Bhowmik, Md. Shafiqul Islam; Supervision: Fahmida Akter, Md. Shafiqul Islam; Validation: Jannatun Nahar Jui, Fahmida Akter; Visualization: Md. Liton Mia, Md. Shafiqul Islam; Writing – original draft: Md. Moshuazzaman, Jannatun Nahar Jui; Writing – review & editing: Md. Liton Mia, Fahmida Akter, Md. Shafiqul Islam.

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Declarations

Conflicts of Interest: The authors declare no conflict of interest.

Institutional/Ethical Approval: The study was approved by Department of Agronomy, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.

Data/Supplementary Information Availability: Not applicable.

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