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ORIGINAL RESEARCH ARTICLE

Determination of fertilizer requirement of Indonesian black rice in winter season under different plant spacing at Agro-ecological Zone-9 of Bangladesh

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ABSTRACT

Indonesian black rice is quite popular for its highly nutritive value and profitable production. The distinct knowledge about optimum fertilizer doses and plant spacing contributes to its promising yield. The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, from December 2022 to May 2023 to find out the effect of fertilizer management and plant spacing on the growth and yield of Indonesian black rice in the winter season. The experiment was conducted with 5 treatments of fertilizer management *viz.*, F_1(70% of recommended doses); F_2(80% of recommended doses); F_3(90% of recommended doses); F_4(100% of recommended doses) and F_5(110% of recommended doses) with 4 plants spacing *viz.*, S_1(20 cm × 15 cm); S_2(20 cm × 20 cm); S_3(25 cm × 15 cm) and S_4(25 cm × 20 cm). The experiment was laid out in a split-plot design where the fertilizer management was allocated in main plots and the plant spacing was distributed in sub -plots with three replications. The result revealed that the fertilizer doses and plant spacings along with the interaction effects significantly influenced the growth and yield parameters of Indonesian black rice. Regarding vegetative growth, plant height (79.3cm), total tiller plant^{-1} (21.27cm), and total leaf number plant^{-1}(58.47) were maximal at 100% recommended dose of fertilizer(F_4) at DAT 65. Similarly, S_2(20 cm × 20 cm) had better result in crop growth and yield attributes. The interaction effects of the treatments showed significant impact on plant height, total tiller and leaf number where F_4S_2 gave satisfied results. The highest values for the yield parameters including the maximum number of grains panicle^{-1}(100.70), 1000-grain weight (28.33g), and grain yield (5.69g) were found from the combination treatment of F_4S_2. On the other hand, the lowest grain (3.68g) yield was found from F_1S_4. Therefore, observing the results of the experiment, the best consideration was F_4S_2 at Agro-ecological Zone-9 in the winter season for the desirable growth and yield of Indonesian black rice.

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INTRODUCTION

Rice (*Oryza sativa* L.) is the widespread cereal crop for nearly 50% of the world's population. In 2020, Asia alone contributed 91% of 514 million metric tons of rice supplements around the world (Rao *et al.*, 2022). Asia is the homeland of *Oryza sativa* and on the other hand, *O. glaberrima* species is native to Africa. Rice can also be classified into two types based on its color, namely white rice and pigmented rice. Rice genotypes with pigmentations have been cultivated for a very long time in Asia. This rice has a renowned legacy and some of its traits formed varieties like "Imperial rice", and "Forbidden rice" which were restricted only for the royal's consumption. China has already produced several varieties of black rice and Indonesian black rice (Ito & Lacerda, 2019). Black rice is superior in phytochemical properties to white rice, which is beneficial to human health as a source of antioxidant, anti-mutagenic, anti-carcinogenic, and anti-diabetic treatment. Most black rice produces secondary metabolites that are transferred to storage organs like grains in the form of phenolics, flavonoids, anthocyanins, vitamins, amino acids, phytosterols, and others (Fitri *et al.*, 2021). Black rice is very effective for many major health issues including heart diseases, diabetes, cholesterol, and constipation. Considering its tremendous benefits, nowadays Europe and the USA are showing enthusiasm to cultivate this rice in mass production (Rahman *et al.*, 2020). Sutrisno *et al.* (2018) found the remarkable biodiversity of rice in Indonesia where it achieves the third position over the world for the richest country in pigmented rice germplasm, after China and Sri Lanka. Research showed that Ketan Putri, Ketan Hitam I, Ketan Hitam II, Gogo Niti II, and other pigmented rice varieties have a wide range of physicochemical, functional, and antioxidant properties, that are useful for the formulations of various products with health benefits (Pradipta *et al.*, 2020). As Indonesia has a diverse climate condition, hence the production system varies from place to place. Proper agronomic management like- seed rate, varieties, plant spacing and other elementary methods keep a great impact on rice growth and yield. One study showed that rice cultivation under appropriate plant spacings with different varieties of aromatic rice increased yield attributes significantly (Saha *et al.*, 2020). Another study reported that fertilizer application had crucial impact on rice yield and other parameters. Therefore the application method, capacity, amount and timing was considered to obtain maximum grain yield (Wu *et al.*, 2021). Under global climate change, it is wise to select appropriate practices like proper irrigation, nutrient management, temporal and spatial management, and other agronomic practices to get better outcome (Das, 2017).

In Bangladesh, maximum rice cultivation is done in winter season which is named by 'Boro season' due to its suitable abiotic factors. Black rice is mainly cultivated in hilly areas in Bangladesh. However, inadequate soil fertility status renders lower production in those areas. This problem can be solved by cultivation with the precise agronomic management in plain land since plain lands have better fertility other than the hilly areas. This experiment was conducted to figure out the appropriate fertilizer dose and plant spacing for an Indonesian black rice with the purpose of getting maximum growth and yield.

MATERIALS AND METHODS

The research was carried out at Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period of December, 2022 to May, 2023. The experimental location is 18 meters above sea level and is situated in the southwest of Brahmaputra at latitude 240 75´ N and longitude 900 50´ E. This site belongs to non-calcareous dark grey floodplain soil under the Agro-ecological Zone Old Brahmaputra Floodplain. Under the Old Brahmaputra Floodplain Agro-ecological zone, the experimental area was a moderately flat, well-drained plot of land that belonged to the Sonatola series of non-calcareous dark grey floodplain soil (UNDP & FAO, 1988).

Agro-climatic condition

The experimental site is situated in the tropical monsoon region. It has a tropical hot humid region starting from March to October and a cool winter from November to February. Monthly weather data during the experimental period (December 2022 to May 2023) is presented in the Figure 1. The data were collected from Department of Irrigation and Water Management, Station: Bangladesh Agricultural University campus.

Experimental treatment and design

The experiment was conducted following two factors *viz.*, A) recommended doses of fertilizers and B) Plant spacings; which were F_1(70% of recommended doses), F_2(80% of recommended doses), F_3(90% of recommended doses), F_4(100% of recommended doses) and F_5(110% of recommended doses) with 4 plants spacing: S_1(20 cm × 15 cm), S_2(20 cm × 20 cm), S_3(25 cm × 15 cm) and S_4(25 cm × 20 cm). The recommended doses of fertilizers were 260, 70, 100, 70 and 7 kg ha^{-1} of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate, respectively, according to Bangladesh Rice Research Institute for one of the high yielding variety (HYV) in the winter season. The experiment was laid out in a split plot design with three replications where fertilizer was allocated in the main plot and spacing was distributed in the subplot. Each plot size was 10 m^2 (4 m × 2.5 m).

Experimental land and layout preparation

The land was opened with a tractor-drawn disc plough and subsequent ploughings and cross ploughings were given and leveled by laddering. Adequate irrigation, organic fertilizer with other intercultural operations were done before the field layout was made. After final land preparation, the transplantation of the Indonesian black rice seedling was done according the selected plant spacings and recommended fertilizer doses on 5^{th} of December, 2022.

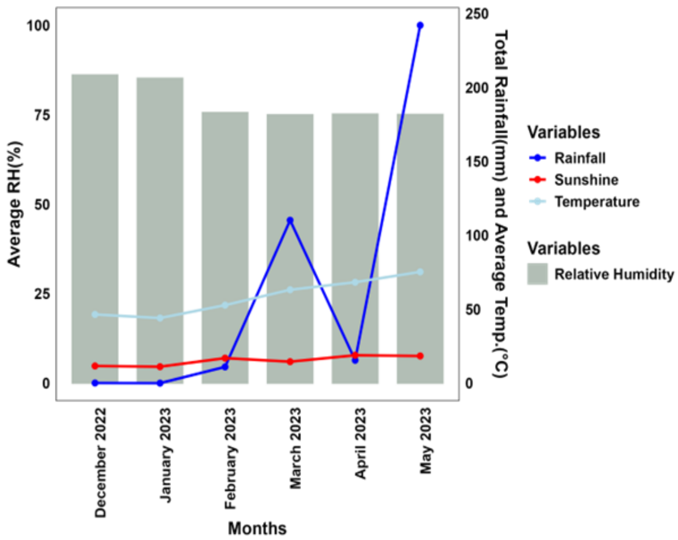

Figure 1. *Monthly weather data during the experiment.*

Crop husbandry

During the final land preparation, all the recommended doses of fertilizers were applied, and the urea was applied into three splits at 15, 30, and 45 days after transplanting (DAT). Various intercultural operations *viz.*, weeding, irrigation, disease, and pest management etc., were done when needed. Regular monitoring of the field during the whole cropping season was maintained to observe the crop growth and development.

Observation and data collection

The crop was harvested at its full maturity. Five rice hill plot^{-1} randomly selected from each plot and uprooted before harvesting for recording data. During the growth period, growth data (plant height, total tillers hill^{-1}, total leaf plant^{-1}) were collected at the interval of 20, 35, 50 and 65 DAT. After harvesting the data on plant height, total tillers hill^{-1}, effective tillers hill^{-1}, non-effective tillers hill^{-1}, panicle length, number of grains panicle^{-1}, number of sterile grains panicle^{-1}, weight of 1000 grains, grain yield, straw yield, biological yield, harvest index were collected. All these data were collected from the previously selected hills, except the yield and harvest index data.

Statistical analysis

The recorded data were statistically analyzed to find out the significance of variation resulting from the experimental treatments. All the collected data were analyzed and adjudged by statistical software R version 4.3.1.

RESULTS AND DISCUSSION

Growth characteristics of black rice

At DAT 20, 35, 50, and 65, the maximum plant heights (31.41cm, 45.5cm, 69.8cm and 79.3cm respectively) were found at 100 % RD of fertilizer (F_4) in this experiment (Figure 2a). In the case of total tiller number hill^{-1} at 50 DAT and 65 DAT, the highest result was (19.41cm and 21.27cm, respectively) and also at the same DATs the utmost total leaf number plant^{-1} (53.58 and 58.47, respectively) were recorded from the application of 100 % RD of fertilizer (F_4) in this study (Figures 2b, c). The lowest parameters of plant height, and total leaf characters (77.28cm and 47.69, respectively) were recorded from 110 % RD of fertilizer application (F_5) at 65 DAT (Figures 2a, c). Additionally, the minimum tiller number hill^{-1} was 15.36 cm at DAT 65 (Figure 2b) from 70% RD of the fertilizer application (F_1). Fertilizer rates had significant impression on rice growth and yield parameters. Optimum rate of the recommended fertilizer gave desirable yield. Yuniarti *et al.* (2024) found the tallest plant (60.34 cm) was observed from recommended doses of NPKS with Si fertilizer and also it had significant value on soil bio-chemical compositions.

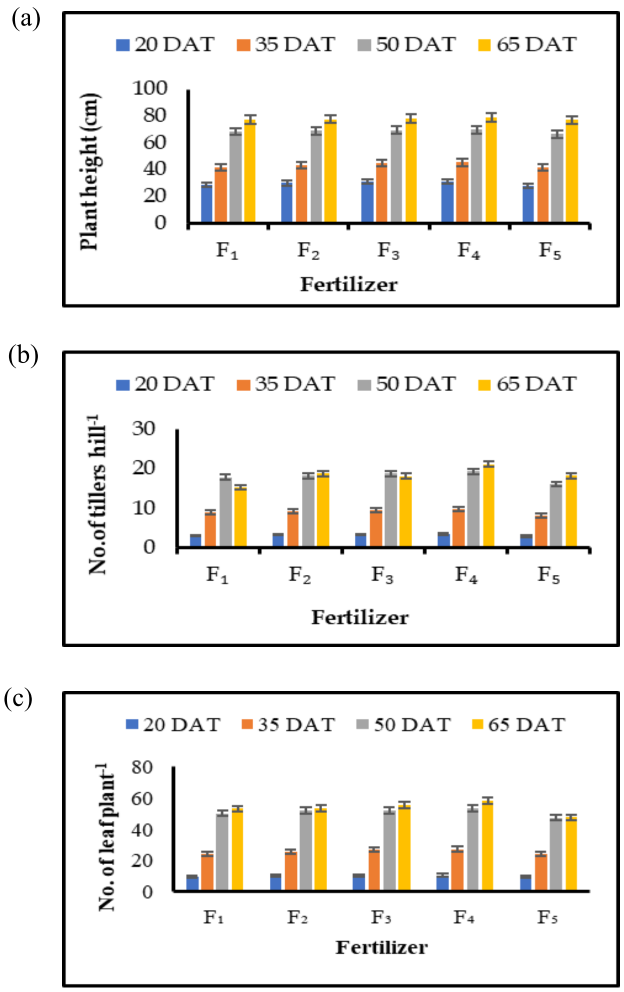

Figure 2 (a-c). *Effect of fertilizer on (a) plant height, (b) number of tiller hill^{-1}, (c) number of leaf plant^{-1} of black rice at different days after transplanting (DATs). Here, F1 =70% RD of Fertilizer, F2=80% RD of Fertilizer, F_3=90% RD of Fertilizer, F_4= 100% RD of fertilizer, F_5= 110% RD of Fertilizer.*

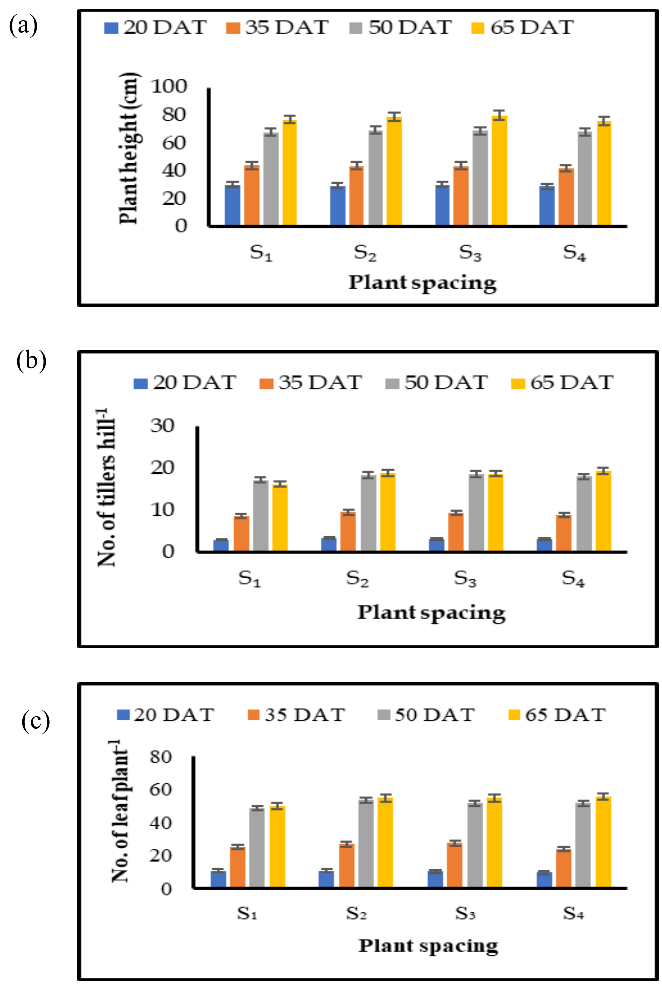

Figure 3 (a-c). *Effect of plant spacing on (a) plant height, (b) number of tiller hill^{-1}, (c) number of leaf plant^{-1} of black rice at different days after transplanting (DATs). Here, S_1(20 cm × 15 cm), S_2(20 cm × 20 cm), S_3(25 cm × 15 cm) and S_4(25 cm × 20 cm).*

Table 1. Interaction effect of fertilizer and plant spacing on the plant height of Indonesian black rice on different days after transplanting.

Fertilizer: Spacing	Plant height (cm)			
	Days after transplanting (DAT)			
	20	35	50	65
F_1:S_1	28.55b-f	44.77a-c	70.55a-c	77.22de-g
F_1:S_2	28.11c-f	43.55a-c	72.22ab	73.66gh
F_1:S_3	28.33c-f	38.11c	67.00b-d	81.44bc
F_1:S_4	29.44a-f	41.55a-c	64.33cd	77.88c-f
F_2:S_1	32.00a-d	44.66a-c	68.33a-d	75.44e-h
F_2:S_2	31.11a-d	42.66a-c	66.00b-d	78.77b-e
F_2:S_3	30.78a-e	45.11ab	70.99ab	77.44c-g
F_2:S_4	26.44ef	41.00a-c	71.22ab	79.78b-d
F_3:S_1	32.77ab	45.66a	69.33a-d	79.77b-d
F_3:S_2	29.22b-f	46.89a	66.55b-d	77.78cd-g
F_3:S_3	32.11a-c	43.55a-c	72.00ab	80.44b-d
F_3:S_4	31.00a-d	43.22a-c	70.66a-c	75.11e-h
F_4:S_1	30.89a-d	44.11a-c	68.33a-d	74.89e-h
F_4:S_2	33.67a	47.44a	74.55a	87.22a
F_4:S_3	31.44a-d	47.11a	68.66a-d	82.44b
F_4:S_4	29.66a-f	43.33a-c	67.66b-d	72.66h
F_5:S_1	27.67d-f	42.00a-c	63.77d	78.33b-e
F_5:S_2	25.89f	38.55bc	67.44b-d	78.11c-e
F_5:S_3	29.44a-f	45.00ab	67.11b-d	78.89b-e
F_5:S_4	28.55b-f	42.33a-c	67.89b-d	73.78f-h
Level of significance	*	*	*	**
CV (%)	8.8	9.35	5.57	7.18

F1 =70% RD of Fertilizer, F2=80% RD of Fertilizer, F_3=90% RD of Fertilizer, F_4= 100% RD of fertilizer, F_5= 110% RD of Fertilizer; S_1(20 cm × 15 cm), S_2(20 cm × 20 cm), S_3(25 cm × 15 cm) and S_4(25 cm × 20 cm). Means having the same letters within the same column do not differ significantly. ** = Significant at 1% level of probability, * = Significant at 5% level of probability.

In the case of plant spacing, at 20 and 65 DAT the tallest plants were (30.42cm, 80.13cm respectively) obtained at S_3 (25 cm × 15 cm) in the findings (Figure 3a). On the other hand, the lowest plant height (29.02cm, 42.29cm, and 75.84cm) was obtained from S_4 (25 cm × 20 cm) at 20, 35 and 65 DAT, respectively (Figure 3a). Regarding the total tiller hill^{-1} maximal value (19.38cm) and for the total leaf number plant^{-1}, the maximum value (56.53cm) was recorded from S_4 (25 cm × 20 cm) plant spacing (Figures 3b, c). In the case of total leaf plant^{-1}, the lowest values at 50 and 65 DAT were (48.46 and 49.95, respectively) observed from S_1 (20 cm × 15 cm) plant spacing (Figure 3c) and 35 DAT was non-significant. Plant spacings had been seen with different results under the DATs in the growth stage of Indonesian black rice. Here the interaction effect between fertilizer management and plant spacing had a significant effect on the plant characteristics. The final date at 65 DAT, numerically the tallest plant (87.22 cm) was recorded from F_4S_2 and the shortest one (72.66 cm) was recorded from F_4S_4 (Table 2). The other sampling dates- 20, 35, and 50 DAT showed the maximum plant height value at F_4S_2 (Table 1). In the case of the total tiller hill^{-1}, the highest value at 65 DAT was (23.27 cm) found at F_4S_2 and the lowest was (12.78 cm) at F_1S_1 treatment (Table 2). Other dates *viz.* 20, 50 DAT showed maximum value at F_4S_2 and the highest value recorded from F_3S_2 at 35 DAT (Table 2). Regarding the leaf number plant^{-1}, at the final 65 DAT the highest value (67.78) was obtained from F_3S_4, and the minimum value was (43.33) found at F_5S_1 (Table 2). For the other sampling dates, in most of the cases, F_4S_2 did the best performance under the total leaf number (Table 3).

Crop characters and yield of black rice

Interaction effect of recommended fertilizer and plant spacing had grate impact on total tiller number, effective tillers, non-effective tillers, and other yield contributing characteristics. In case of the interaction effect, the highest number of the effective tiller hill^{-1} (14.13) was found at F_4S_1 and the lowest (9.10) was found at F_5S_1 (Table 5). Regarding the non-effective tiller, the highest value (3.83) was found from F_5S_1 and the lowest value (0.17) was found from F_1S_1 (Table 4). For panicle length, the maximum value (25.37) was found from F_3S_3 which was statistically similar to F_4S_2 and the minimum (22.53 cm) was found from F_5S_4 (Table 4). Sterile spikelet panicle^{-1} was non-significant and there was no influence of the interaction effects. The highest no. of grains panicle^{-1} was (100.70) in the combination of F_4S_2 and the lowest (77.67) was detected at F_5S_4 (Table 5). Appropriate plant spacing during plantation provided better yield rather than narrow-spaced or distant planting in crop production. A Significant effect of plant spacing and N fertilizer on plant yield characteristics had been found in another study regarding rice cultivation where the number of tillers and grain was in a desirable amount. Excessive plant spacing intended weed infestation which was detrimental to rice growth and yield (Erythrina *et al.*, 2023).

The right amount of fertilizer with optimum plant spacing brought high yield and increased the quality of the rice plant characters. It might be due to get the desirable plant population under proper agronomic management stated by Aparna *et al.* (2022). The interaction effect, numerically the highest 1000-grain weight (28.33 g), grain yield (5.69 t ha^{-1}) was obtained from

Table 2. *Interaction effect of fertilizer and plant spacing on the total tiller hill^{-1} of Indonesian black rice on different days after transplanting.*

Fertilizer: Spacing	Number of tillers hill^{-1}			
	Days after transplanting (DAT)			
	20	35	50	65
$F_1:S_1$	3.22b-f	8.22bc	16.89a-c	12.78j
$F_1:S_2$	3.11c-f	8.89a-c	17.22a-c	18.33c-f
$F_1:S_3$	2.88d-f	10.55ab	18.66ab	14.22ij
$F_1:S_4$	2.78d-f	8.33bc	19.00ab	16.11f-j
$F_2:S_1$	2.55f	9.00a-c	18.22a-c	14.44h-j
$F_2:S_2$	3.89a-c	9.55a-c	18.22a-c	19.55b-e
$F_2:S_3$	2.77d-f	9.44a-c	19.11ab	17.44d-i
$F_2:S_4$	3.99ab	9.11a-c	17.66a-c	23.77a
$F_3:S_1$	3.44a-e	8.11bc	18.44a-c	14.77g-j
$F_3:S_2$	3.22b-f	11.55a	17.88a-c	16.44e-i
$F_3:S_3$	3.44a-e	8.55bc	19.77ab	21.22a-c
$F_3:S_4$	3.55a-d	10.22ab	19.11ab	20.33b-d
$F_4:S_1$	3.33b-f	9.55a-c	18.89ab	20.66a-d
$F_4:S_2$	4.22a	10.89ab	21.33a	22.89ab
$F_4:S_3$	3.89a-c	9.55a-c	19.22ab	22.55ab
$F_4:S_4$	2.66ef	9.00a-c	18.22a-c	19.00c-f
$F_5:S_1$	2.66ef	8.11bc	13.99c	18.77c-f
$F_5:S_2$	3.22b-f	7.22c	17.33a-c	18.00c-g
$F_5:S_3$	2.72ef	9.11a-c	16.78a-c	18.55c-f
$F_5:S_4$	3.22b-f	8.33bc	16.44bc	17.67d-h
Level of significance	**	*	*	**
CV (%)	14.81	15	15.37	11.04

F1 =70% RD of Fertilizer, F2=80% RD of Fertilizer, F_3=90% RD of Fertilizer, F_4= 100% RD of fertilizer, F_5= 110% RD of Fertilizer; S_1 (20 cm × 15 cm), S_2 (20 cm × 20 cm), S_3 (25 cm × 15 cm) and S_4 (25 cm × 20 cm). Means having the same letters within the same column do not differ significantly. ** = Significant at 1% level of probability, * = Significant at 5% level of probability.

Table 3. Interaction effect of fertilizer and plant spacing on the Number of leaf plant^{-1} of Indonesian black rice on different days after transplanting.

Fertilizer: Spacing	Number of leaf plant-^{1}			
	Days after transplanting (DAT)			
	20	35	50	65
$F_1:S_1$	9.44d-g	22.55b	48.99ab	54.44b-g
$F_1:S_2$	10.55a-f	22.33b	48.55ab	51.77c-h
$F_1:S_3$	9.00fg	28.00ab	53.66a	53.44c-g
$F_1:S_4$	11.00a-f	24.78ab	50.11ab	53.11c-g
$F_2:S_1$	11.00a-f	25.22ab	49.33ab	45.66f-h
$F_2:S_2$	9.88c-g	27.78ab	56.78a	47.33e-h
$F_2:S_3$	11.44a-d	25.00ab	50.66ab	63.55ab
$F_2:S_4$	8.11g	24.55ab	51.88ab	56.66b-e
$F_3:S_1$	11.22a-e	29.77ab	50.33ab	46.55f-h
$F_3:S_2$	9.77cd-g	28.44ab	51.33ab	57.66b-d
$F_3:S_3$	10.88a-f	26.11ab	51.55ab	51.00d-h
$F_3:S_4$	10.44b-f	24.44ab	56.00a	67.78a
$F_4:S_1$	9.33d-g	24.11ab	51.44ab	59.78a-d
$F_4:S_2$	12.66a	31.89a	58.78a	61.11a-c
$F_4:S_3$	11.89a-c	30.55ab	53.66a	60.00a-d
$F_4:S_4$	9.00fg	23.11b	50.44ab	53.00c-g
$F_5:S_1$	12.33ab	23.66ab	42.22b	43.33h
$F_5:S_2$	10.00c-g	23.11b	50.99ab	55.11b-f
$F_5:S_3$	8.22g	27.11ab	48.00ab	45.22gh
$F_5:S_4$	9.22e-g	22.99b	48.89ab	47.11e-h
Level of significance	**	*	*	**
CV (%)	12.55	9.27	12.89	10. 73

F1 =70% RD of Fertilizer, F2=80% RD of Fertilizer, F_3=90% RD of Fertilizer, F_4= 100% RD of fertilizer, F_5= 110% RD of Fertilizer; S_1 (20 cm × 15 cm), S_2 (20 cm × 20 cm), S_3 (25 cm × 15 cm) and S_4 (25 cm × 20 cm). Means having the same letters within the same column do not differ significantly. ** = Significant at 1% level of probability, * = Significant at 5% level of probability.

Table 4. Effect of Fertilizer and plant spacing on crop characteristics of Indonesian black rice.

Fertilizer: Spacing	No. of total tillers hill^{-1}	No. of sterile spikelet panicle^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	Harvest index (%)
F_1:S_1	10.93b	20.17	0.17b	24.37a-c	45.83a-c
F_1:S_2	14.07ab	19.90	1.4ab	24.83ab	46.37a-c
F_1:S_3	10.27b	23.98	0.67ab	23.7a-c	49.08ab
F_1:S_4	13.93ab	22.87	1.40ab	23.43a-c	43.25c
F_2:S_1	13.67ab	23.53	1.40ab	25.20a	45.28a-c
F_2:S_2	13.40ab	25.33	1.00ab	24.47a-c	47.08a-c
F_2:S_3	12.73ab	23.43	0.93ab	24.07a-c	44.83a-c
F_2:S_4	10.73b	18.77	0.93ab	22.93bc	43.50bc
F_3:S_1	12.40ab	23.03	1.33ab	23.87a-c	47.60a-c
F_3:S_2	14.80a	21.17	1.80ab	24.03a-c	46.93a-c
F_3:S_3	12.00ab	21.97	0.53ab	25.37a	44.22a-c
F_3:S_4	12.33ab	27.37	0.67ab	23.63a-c	47.70a-c
F_4:S_1	15.20a	23.60	1.07ab	24.30a-c	48.08a-c
F_4:S_2	11.87ab	18.70	0.87ab	24.93a	48.32a-c
F_4:S_3	12.33ab	22.03	0.73ab	24.27a-c	45.51a-c
F_4:S_4	13.07ab	19.03	1.40ab	24.00a-c	46.12a-c
F_5:S_1	12.93ab	27.37	3.83a	23.80a-c	47.19a-c
F_5:S_2	13.73ab	25.77	1.00ab	24.40a-c	47.14a-c
F_5:S_3	13.27ab	22.27	2.80ab	22.93bc	46.75a-c
F_5:S_4	10.60b	19.73	0.73ab	22.53c	49.17a
Level of significance	*	NS	*	*	*
CV (%)	15.12	15.08	12.43	5.88	7.29

F_1=70% RD of Fertilizer, F_2= 80% RD of Fertilizer, F_3= 90% RD of Fertilizer, F_4= 100% RD of Fertilizer, F5 =110% RD of Fertilizer; S_1 (20 cm × 15 cm), S_2 (20 cm × 20 cm), S_3 (25 cm × 15 cm) and S_4 (25 cm × 20 cm. Means having the same letters within the same column do not differ significantly. ** = Significant at 1% level of probability, * = Significant at 5% level of probability.

Table 5. Interaction effect of fertilizer and plant spacing on yield attributes and yield of Indonesian black rice.

Fertilizer: Spacing	No. of effective tillers hill^{-1}	No. of grains panicle^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
F_1:S_1	10.77b-e	85.67c-g	28.07a-c	3.96d-g	4.65cd
F_1:S_2	12.67a-d	86.33b-g	27.37a-f	4.45b-g	5.16a-d
F_1:S_3	9.60de	93.00a-d	26.30fg	4.00c-g	4.15d
F_1:S_4	12.53a-d	82.93d-g	27.13a-f	3.68g	4.90cd
F_2:S_1	12.27a-d	92.73a-d	26.85c-g	3.87e-g	4.69cd
F_2:S_2	12.40a-d	96.57ab	26.78d-g	4.68a-g	5.25a-d
F_2:S_3	11.80a-e	80.07fg	28.25ab	4.06c-g	5.04b-d
F_2:S_4	9.80c-e	79.57fg	27.72a-e	3.75fg	4.86cd
F_3:S_1	11.07a-e	94.60a-c	26.53e-g	5.09a-c	5.61a-c
F_3:S_2	13.00ab	91.37a-d	27.52a-f	5.55a	6.26a
F_3:S_3	11.47a-e	84.87c-g	28.25ab	4.40b-g	5.57a-c
F_3:S_4	11.67a-e	80.73e-g	27.37a-f	4.98a-d	5.39a-c
F_4:S_1	14.13a	89.33b-f	27.52a-f	5.34ab	5.74a-c
F_4:S_2	11.00b-e	100.70a	28.33a	5.69a	6.08ab
F_4:S_3	11.60a-e	90.90a-e	27.05b-g	4.78a-f	5.65a-c
F_4:S_4	11.67a-e	87.77b-g	27.90a-d	4.75a-g	5.56a-c
F_5:S_1	9.10e	83.3d-g	26.87c-g	4.97a-e	5.55a-c
F_5:S_2	12.73a-c	93.27a-d	26.45fg	5.07a-c	5.71a-c
F_5:S_3	10.47b-e	77.87g	26.72d-g	4.74a-g	5.43a-c
F_5:S_4	9.87c-e	77.67g	25.85g	4.90a-e	5.07b-d
Level of significance	*	*	*	*	*
CV (%)	16.08	7.28	5.75	14.19	12.84

F_1=70% RD of Fertilizer, F_2= 80% RD of Fertilizer, F_3= 90% RD of Fertilizer, F_4= 100% RD of Fertilizer, F5 =110% RD of Fertilizer; S_1 (20 cm × 15 cm), S_2 (20 cm × 20 cm), S_3 (25 cm × 15 cm) and S_4 (25 cm × 20 cm. Means having the same letters within the same column do not differ significantly. ** = Significant at 1% level of probability, * = Significant at 5% level of probability.

F_4S_2 and maximum straw yield (6.26 t ha^{-1}) resulted from F_2S_3 (Table 5). The lowest data for 1000-grain weight (25.85 g) was recorded from F_5S_4 (Table 5). The lowest grain yield (3.68 g t ha^{-1}) was found when the crop was planted with F_1S_4 and the lowest straw yield (4.15 t ha^{-1}) was found in F_1S_3 (Table 5). Result revealed that the highest harvest index (49.17%) was recorded from F_5S_4 which was statistically seen at a similar range to F_4S_2 (Table 4). On the other hand, the lowest harvest index (43.25%) was obtained from the interaction between F_1S_4 (Table 4). Plant density, seedling quantity, recommended fertilizer and other agronomic-management practices showed positive results on rice vegetative growth and yield. It might be due to the interaction effect of agronomic management with the phytochemicals and plant fertilizer up taking mechanism of the rice plant (Thapa *et al.*, 2019).

Conclusion

Fertilizer and plant spacing had a paramount impact on the growth and yield of Indonesian black rice. Most of the parameters like plant height, total tiller number, effective tiller, grain yield, 1000 grain weight were influenced by the recommended fertilizer dose of F_4. On the other side, S_2 plant spacing gave maximum results on most of the plant characters. It was a clear outline that appropriate fertilizer doses and plant spacing had significance on most of the characteristics of the Indonesian black rice. The interaction effects of F_4S_2 contributed better result than the other treatments. Based on the results of the study, it can be concluded that the performance of 100% recommended doses of fertilizer with plant spacing at 20 cm × 20 cm gave a satisfactory performance considering the growth and yield of Indonesian black rice in the winter season at Agro-ecological Zone-9 of Bangladesh.

DECLARATIONS

Author contribution statement

Conceptualization: J.F.S. and R.R.; Methodology: J.F.S. and R.R.; Software and validation: J.F.S. and R.R.; Formal analysis and investigation: J.F.S.; Resources: J.F.S.; Data curation: J.F.S.; Writing—original draft preparation: J.F.S.; Writing—review and editing: J.F.S., R.R., S.Y.; Visualization: J.F.S., S.Y., R.R.; Supervision: R.R.; Project administration: J.F.S.; Funding acquisition: J.F.S. All authors have read and agreed to the published version of the manuscript.

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