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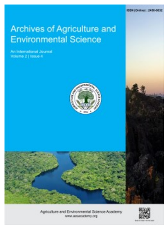

ORIGINAL RESEARCH ARTICLE

CrossMark

Yield performance of aromatic fine rice as influenced by nitrogen fertilization and weed control techniques

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ABSTRACT

Nitrogen fertilization and weed management is the major concern to yield maximization of rice. The study was conducted to assess the influence of nitrogen and weed control to yield improvement of aromatic rice BRRI dhan34. The experiment included three nitrogen levels *viz.* 50, 100 and 150 kg N ha^{-1} as well as three weeding schedules *viz.* one hand weeding at 15 days after transplanting (DAT), two hand weeding at 15 and 30 DAT and three hand weeding at 15, 30 and 45 DAT. The experiment was conducted with randomized complete block design. The findings demonstrated important correlations between weeding techniques, nitrogen levels and yield components. When the crop was fertilized with 50 kg N ha^{-1} the highest numbers of total tillers hill^{-1} (8.53), effective tillers hill^{-1} (7.51), grains panicle^{-1} (128.0) and grain yield (3.97 t ha^{-1}) were resulted. Regarding weeding practices, two manual weeding carried out at 15 and 30 DAT reported the highest numbers of effective tillers hill^{-1} (7.62), grains panicle^{-1} (128.1) and grain yield (4.10 t ha^{-1}). The highest effective tillers hill^{-1} (8.33), the most grains panicle^{-1} (129.8), the grain yield (4.36 t ha^{-1}) and straw yield (6.40 t ha^{-1}) were found in two hand weeding at 15 and 30 DAT combined with 50 kg N ha^{-1} and the lowest grain yield (3.53 t ha^{-1}) was obtained from one hand weeding given at 15 DAT along with 150 kg N ha^{-1}. Therefore, the study demonstrated that BRRI dhan34 can be fertilized with 50 kg N ha^{-1} along with two hand weeding at 15 and 30 DAT to obtained higher yield.

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INTRODUCTION

The majority of Bangladesh's agricultural production is produced through the cultivation of rice (*Oryza sativa* L.). Rice comprises 91.1% of the country's total grain production, provides 74% of Bangladeshis' daily caloric needs. The demand for rice is expected to rise globally by 25% between 2001 and 2025 in order to keep up with population expansion (Maclean *et al.*, 2002). The average rice production in Bangladesh is 2.72 t ha^{-1} which is incredibly small (BBS, 2022). *Aman* is the second largest rice crop in the country in terms of output volume and aromatic rice covers small portion of the total transplanted *Aman* (Adhikari *et al.*, 2018; Roy *et al.*, 2018). Both for internal use and export, the demand for fragrant rice has grown dramatically in recent years. These are regarded as the highest quality rice and sell for substantially more money in overseas markets than high grade non-aromatic rice (Roy *et al.*, 2020). These distinguishing traits include fineness, smell, taste and protein content. Bangladesh has a bright prospect for export of fine rice thereby earning foreign exchange (Sarkar *et al.*, 2014; Mushtaree *et al.*, 2022). For better grain production, nitrogen one of the necessary components must be present in appropriate quantities during the early, middle and panicle initiation periods of the rice plant. Nitrogen is a component that is commonly required for rice to generate a high yield (Saha *et al.*, 2012; Khatun *et al.*, 2023). Nitrogen fertilizer increases the yields of grain, straw and vegetative growth (Chowdhury *et al.*, 2016; Paul *et al.*, 2021). Too little nitrogen can make it difficult to grow rice while too much nitrogen can induce lodging in plants and a decrease in production (Jisan *et al.*, 2014; Jahan *et al.*, 2017). Therefore, nitrogen should be administered sparingly to get a respectable yield.

The capacity to grow and procreate in vast numbers despite difficult environmental conditions makes weed a nutrient absorbing, competitive plant that invades its native habitat on its own. It also possesses other characteristics that increase productivity. A heavy weed infestation is one of the reasons for low rice production (Mamun, 1988). Losses caused by weeds vary from one country to another, depending on the predominant weed flora and on the control, methods practiced (Sarkar *et al.*, 2017). According to Mamun *et al.* (1993), the competitive features of weeds have a considerable negative influence on agricultural productivity and are to liability for significant yield losses. The most popular and time-consuming method of weed management in our country is still manual weeding (Miah *et al.*, 2023). Hand weeding is becoming more and more important when there is no pesticide that can successfully control a certain weed or when the expense of herbicides makes them prohibitive for farmers, especially small-scale farmers (Paul *et al.*, 2019). Determining the optimal nitrogen levels and effective weeding methods for crops to attain a satisfactory yield demands extensive research. This study aimed to identify the best nitrogen application rate and appropriate weeding practices to maximize the grain yield of BRRI dhan34.

MATERIALS AND METHODS

Experimental site and experimentation

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during July to December 2016. The experimental site was situated at latitude of 24°75' N and a longitude of 90°50' E, with an elevation of 18 meters above sea level. This location falls within the Old Brahmaputra Floodplain specifically in the Sonatola Soil Series of Agricultural Ecological Zone 9 (AEZ-9) (UNDP and FAO, 1988). The soil in the experimental area was characterized by non-calcareous dark grey floodplain soil which had a nearly neutral pH of 6.5, low organic matter content and fertility. The soil texture was silty loam and the land type was classified as medium high. The experiment consisted of various treatments including three different nitrogen levels *viz.* 50, 100 and 150 kg N ha^{-1} and three different weeding schedules viz. one hand weeding at 15 DAT, two hand weedings at 15 and 30 DAT, and three hand weedings at 15, 30 and 45 DAT. The experimental design followed a randomized complete block design and replicated three times. Within each replication, there were nine-unit plots and the allocation of treatment combinations to these unit plots was done randomly. In total, there were 27 unit plots each measuring 4.0 meters by 2.5 meters with distances of 0.75 meters between unit plots and 1.0 meter between replications. The weather patterns observed during the experiment are illustrated in (Figure 1) (Source: Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh).

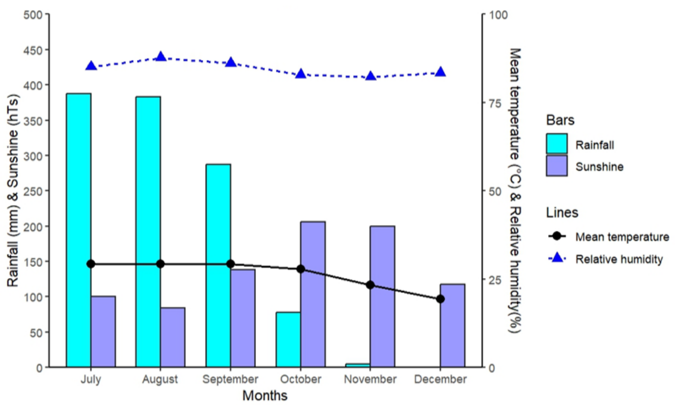

Figure 1. *Distribution of monthly temperature, relative humidity, sunshine hour and rainfall of the experimental site during the crop growth period (July to December 2016).*

Crop husbandry

BRRI dhan34, a high-yielding variety of aman rice, was introduced by the Bangladesh Rice Research Institute (BRRI). This aromatic, fine-grain rice is typically cultivated during the Transplant *Aman* season. The seeds of this fine rice variety (cv. BRRI dhan34) were sourced from the Agronomy Field Laboratory at Bangladesh Agricultural University. The selection of healthy seeds was carried out using a specific gravity method. Afterward, the seeds were soaked in water for 24 hours and the soaked seeds were then densely packed in gunny bags. Sprouting occurred within 48 hours and the seedlings were transplanted 72 hours after soaking. These seedlings were nurtured in a medium-high land area with a seedling nursery prepared through soil puddling. The sprouted seeds were sown in this wet nursery bed and proper care was taken to ensure their healthy growth, without the use of fertilizer in the nursery bed. During transplanting into the main field, three seedlings were planted per hill. Land preparation involved several steps, including tractor-drawn disc ploughing, power tiller operation, thorough puddling, cross ploughing with a country plough, and laddering to achieve suitable soil tilth. Weeds and stubble were manually removed from the field before seedling transplantation, and field layout was designed accordingly after land preparation. In terms of fertilization, the experimental plots were treated with triple super phosphate, muriate of potash, gypsum and zinc sulphate during the final land preparation at specified rates. Urea was applied as top dressing in three equal splits at 15, 30 and 45 days after transplanting, following treatment guidelines. Prior to uprooting the seedlings, the nursery bed was watered and healthy, uniform-sized seedlings were carefully selected for transplantation. Intercultural operations, such as weeding, irrigation and pest and disease control, were carried out as needed throughout the crop's growth cycle. Harvesting occurred when the crop reached full maturity, indicated by 90% of the grains turning a golden color. Data on crop characteristics and yield components were recorded by selecting five hills from each unit plot (excluding border rows and the central 1.0 m × 1.0 m area) in preparation for harvesting. The central 1.0 m^2 areas were harvested to record data on grain and straw yields. The harvested crop was threshed using a pedal thresher and the fresh weights of grain and straw were recorded for each plot. Subsequently, the grain and straw yields per plot were recorded and converted to t ha^{-1}.

Data collection

To gather information on crop characteristics and yield components, five hills were randomly chosen from each unit plot, excluding the border rows and the central harvest area measuring 2.0 meters by 2.5 meters. These selected hills were uprooted. Subsequently, the crop from the central 2.0 meters by 2.5 meters area was harvested and each plot's crop was tagged and bundled separately. These bundles were then taken to the threshing floor. After hand threshing, the grains were washed and they were subsequently sun-dried to achieve a moisture level of 14%. Adequate drying was also ensured for the straw. The yields of grain and straw per plot were then measured and converted to t ha^{-1}.

Statistical analysis

The recorded data were compiled and organized for statistical analysis. The analysis of variance (ANOVA) technique was employed using the computer software package MSTAT-C. Mean differences among the treatments were assessed using Duncan's Multiple Range Test (Gomez & Gomez, 1984).

RESULTS AND DISCUSSION

Infested weed species in the experimental field

The weeds that can be found in fragrant rice fields include broad leaved grasses and sedges. The same circumstances that allow for the cultivation of fragrant rice also allow for the wild proliferation and competition with agricultural plants of some weed species. Eleven weed species from five distinct family invasions were found in the test field (Table 1). The eleven weed species included four sedges, three with broad leaves and three grasses.

Growth parameters

Plant height

In this study, nitrogen levels, weeding techniques and their interactions at 45 and 60 days after transplanting had a substantial impact on plant height, a vital measure of crop development. The administration of nitrogen had a discernible effect on plant height at 60 DAT (Figure 2a). A plot treated with 100 kg N ha^{-1} produced the tallest plants (115.1 cm), whereas a plot treated with 50 kg N ha^{-1} produced the shortest plants (111.2 cm). We found it that the latter was statistically similar to the plant height in the plots with 150 kg N ha^{-1}. This implies a distinct dose-response connection between the amount of nitrogen applied and the height of the plants, with the tallest plants growing at the intermediate rate of 100 kg N ha^{-1}. Similar to this, at 60 DAT, weeding techniques were obviously correlated with plant height (Figure 2b). The plots with a single hand weeding at day 15 of the experiment had the tallest plants (114.24 cm) and the plots with three weeding at days 15, 30 and 45 of the experiment had the shortest plants (112.11 cm), which were statistically equivalent to plots with two hand weeding. Additionally, weeding methods and nitrogen levels interacted significantly to affect plant height (Table 2). The height of the plants ranged between 65.40 cm and 69.50 cm in different treatment combinations. One hand weeding at 30 DAT and 50 kg N ha^{-1} application resulted in the tallest plants (69.50 cm) demonstrating the favorable connection between nitrogen treatment and appropriate weeding time. In contrast, the plots with the shortest plants (65.40 cm) underwent two manual weeding at 30 and 45 DAT and received 100 kg N ha^{-1} emphasizing the need of combining nutrient management with effective weeding methods. The stimulatory effect of nitrogen fertilizer on a number of physiological processes within the plant, including cell division and cell elongation, may be responsible for the relationship between nitrogen fertilizer application and plant height. This behavior is consistent with the observations made by Zhilin *et al.* (1997) and Khatun *et al.* (2023), who both found that nitrogen administration significantly increased plant height. In addition, Chandra & Pandey (2001) found that manual weeding was the most efficient strategy for lowering weed dry matter buildup and nitrogen depletion.

Table 1. Infesting species of weeds in the experimental field of aromatic rice.

S. No.	Local name	Scientific name	Family	Life cycle
1	Shama	*Echinochloa crus-galli (L.)* P. Beauv.	Gramineae	Annual
2	Arail	*Leersia hexandra Swartz*	Gramineae	Annual
3	Panikachu	*Monochoria vaginalis (Burm. F.)* C. Presl	Pontederiaceae	Perennial
4	Sabuj Nakphul	*Cyperus difformis* L.	Cyperaceae	Annual
5	Chechra	*Scirpus mucronatus*	Cyperaceae	Annual
6	Keshuti	*Eclipta alba* L.	Compositae	Annual
7	Angta	*Panicum repens* L.	Gramineae	Perennial
8	Panimorich	*Poligonum orientale* L.	Poligonaceae	Annual
9	Anguleeghash	*Digitaria sanguinalis* L.	Gramineae	Annual
10	Topapana	*Pistia stratioter*	Araceae	Perennial
11	Chela ghash	*Parapholis incurva*	Gramineae	Perennial

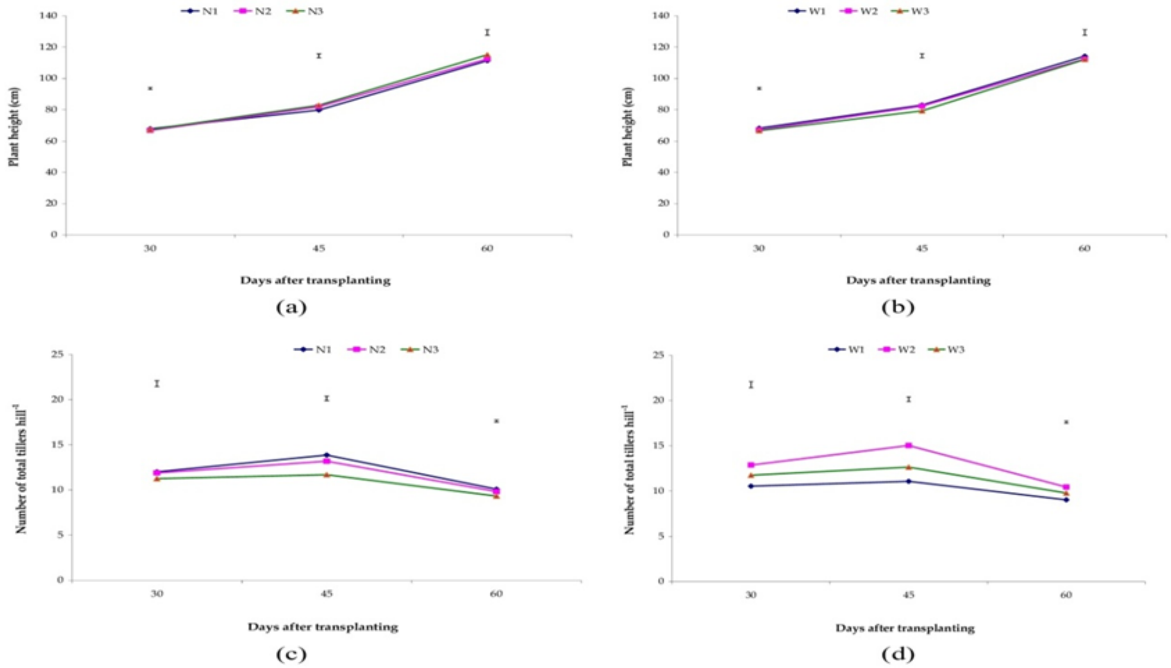

Figure 2. *Effect of level of nitrogen and weeding regimes on plant height and total tillers hill^{-1} at different days after transplanting. Here, N_1 = 50 N kg ha^{-1}; N_2 = 100 N kg ha^{-1}; N_3 = 150 N kg ha^{-1}, W_1 = one hand weeding at 15 DAT; W_2 = Two hand weeding at 15 and 30 DAT; W_3 = Three hand weeding at 15, 30 and 45 DAT.*

Table 2. Interaction effects of level of nitrogen and weeding regime on plant height at different days after transplanting of fine rice (cv. BRRI dhan34).

Interaction (Level of N × weeding regime)	Plant height (cm) Days after transplanting (DAT)		
	30	45	60
$N_1 \times W_1$	69.50a	78.88	112.08
$N_1 \times W_2$	65.92bc	82.25	111.42
$N_1 \times W_3$	67.83ab	78.00	110.33
$N_2 \times W_1$	67.58bc	85.67	113.58
$N_2 \times W_2$	67.08bc	81.83	110.82
$N_2 \times W_3$	65.40c	78.25	112.92
$N_3 \times W_1$	67.42abc	84.25	117.07
$N_3 \times W_2$	67.92ab	82.67	115.00
$N_3 \times W_3$	66.33bc	81.38	113.08
$S\bar{x}$	0.661	1.30	0.98
Sig. level	*	NS	NS
CV (%)	1.70	2.76	1.51

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), * = Significant at 5% level of probability, NS = Not significant, N_1 = 50 N kg ha^{-1}; N_2 = 100 N kg ha^{-1}; N_3 = 150 N kg ha^{-1}; W_1 = one hand weeding at 15 DAT; W_2 = Two hand weeding at 15 and 30 DAT; W_3 = Three hand weeding at 15, 30 and 45 DAT.

Number of total tillers hill^{-1}

The findings demonstrate that the number of tillers hill^{-1} was significantly influenced by nitrogen levels, weeding methods and their interactions at 30, 45 and 60 days after transplanting (DAT). According to (Figure 2c), the largest number of tillers hill^{-1} (13.86) was recorded at 45 DAT with 50 kg of nitrogen per hectare, whereas the lowest number (11.69) occurred at 45 DAT with 150 kg of nitrogen per hectare. The two hand weeding procedures at 15 and 30 DAT produced the highest number of total tillers hill^{-1} (15.03), as shown on (Figure 2d). On the other side, the lowest count, which was achieved with just one hand weeding operation, was 15 DAT. Regarding the interactions between nitrogen levels and weeding methods (Table 3) demonstrates that the conditions with the greatest number of tillers hill^{-1} (13.58) at 30 DAT also included two weeding at 15 and 30 DAT and 50 kg of nitrogen ha^{-1}. The lowest number of tillers hill^{-1} (9.75) was seen when only one hand weeding was carried out at 15 DAT combined with 50 kg of nitrogen ha^{-1}. A research was carried out by Singh *et al.* (1999) to determine the effects of various weed management techniques on weed growth, crop production, and nitrogen uptake in transplanted rice. Their research showed that weeds removed a large amount of nitrogen, 12.97 kg ha^{-1}, when allowed to grow unfettered until they reached maturity. The grain and straw yields in this unweeded control setting were interestingly comparable to those achieved after three weeding cycles. According to research by Kabiraj *et al.* (2020) and Dubey *et al.* (1991), plots that had not been weeded had the highest numbers of worthless tillers and sterile spikelets.

Table 3. Interaction effects of level of nitrogen and weeding regime on number of total tillers hill^{-1} at different days after transplanting of fine rice (cv. BRRI dhan34).

Interaction (Level of N × weeding regime)	Number of total tillers hill^{-1} Days after transplanting (DAT)		
	30	45	60
$N_1 \times W_1$	9.75g	12.08	9.50
$N_1 \times W_2$	13.58a	16.25	10.83
$N_1 \times W_3$	12.67b	13.25	9.92
$N_2 \times W_1$	11.25e	11.38	9.08
$N_2 \times W_2$	12.67ab	15.50	10.50
$N_2 \times W_3$	11.75d	12.67	9.90
$N_3 \times W_1$	10.58a	9.75	8.48
$N_3 \times W_2$	12.33c	13.33	10.00
$N_3 \times W_3$	10.83f	12.00	9.50
$S\bar{x}$	0.093	0.380	0.189
Level of sig.	**	NS	NS
CV (%)	1.38	5.10	3.35

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), * = Significant at 5% level of probability, NS = Not significant, N_1 = 50 N kg ha^{-1}; N_2 = 100 N kg ha^{-1}; N_3 = 150 N kg ha^{-1}; W_1 = one hand weeding at 15 DAT; W_2 = Two hand weeding at 15 and 30 DAT; W_3 = Three hand weeding at 15, 30 and 45 DAT.

Table 4. Effect of level of nitrogen on crop characters, yield components and yield of fine rice (cv. BRRI dhan34).

Nitrogen level	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Grains panicle^{-1} (no)	1000- grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
N_1	147.72	8.53 a	7.51a	128.0a	19.69a	9.98a	39.74a
N_2	145.31	8.08b	6.82b	124.9ab	18.98ab	9.57b	39.26ab
N_3	144.03	7.99b	6.66b	121.8b	18.59b	9.51b	38.75b
$S\bar{x}$	1.25	0.059	0.071	1.33	0.265	0.043	0.198
Sig. level	NS	**	**	**	*	**	**
CV (%)	2.58	2.14	3.03	3.19	4.17	1.36	1.51

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), ** = Significant at 1% level of probability, * = Significant at 5% level of probability; NS = Not significant; N_1 = 50 N kg ha^{-1}; N_2 = 100 N kg ha^{-1}; N_3 = 150 N kg ha^{-1}.

Crop characters, yield components and yield

Plant height

The nitrogen amount and interactions impact did not significantly affect plant height, but the weeding regimen did. The plant with the maximum height (147.72 cm) was identified in a 50 kg N ha^{-1} environment. In 150 kg N ha^{-1}, the lowest plant height (144.03) was discovered (Table 4). The lowest plant height (143.56 cm) was discovered in three weeding at 15, 30 and 45 DAT, while the maximum plant height (148.36 cm) was discovered in one hand weeding at 15 DAT (Table 5). The lowest plant height (141.50 cm) was discovered in three weeding operations at 15, 30 and 45 DAT with 100 kg N ha^{-1}, whereas the maximum plant height (149.92 cm) was discovered in one hand weeding at 15 DAT with 50 kg N ha^{-1} (Table 6). It was found in research Sahrawat *et al.* (1999) and Khatun *et al.* (2023) that nitrogen levels had a significant impact on plant height. It has been shown that higher nitrogen levels cause plants to grow much taller. Additionally, studies by Kabiraj *et al.* (2020) showed that weeds have a suppressive effect on plant height, mostly through competing with plants for nutrients or other elements required to their growth.

Number of total tillers hill^{-1}

The overall number of tillers hill^{-1} was significantly influenced by nitrogen levels. The application of 50 kg of nitrogen ha^{-1} resulted in the highest total number of tillers hill^{-1} (8.53), closely followed by 100 kg of nitrogen ha^{-1} and the lowest total number (7.99) was seen when 150 kg of nitrogen ha^{-1} was used (Table 4). The overall number of tillers hill^{-1} also significantly varied depending on the weeding strategy chosen (Table 5). Due to their capacity to absorb more sun energy, two weeding operations at 15 and 30 DAT resulted in the largest total number of tillers hill^{-1} (8.75). On the other hand, simply one hand weeding at 15 DAT resulted in the lowest number of tillers hill^{-1} (7.77). Additionally, the total number of tillers hill^{-1} was significantly impacted by the interplay between the nitrogen level and the weeding schedule. The two weeding at 15 and 30 DAT along with 50 kg of nitrogen ha^{-1} resulted in the largest number of tillers hill^{-1} (9.25). On the other side, when one hand weeding was done at 15 DAT with 150 kg of nitrogen ha^{-1}, the lowest total tillers hill^{-1} (7.57) were found (Table 6). These results are consistent with earlier study, which showed that the application of nitrogen enhanced the total tillers hill^{-1} (Sarkar *et al.*, 2017). This result is most likely attributable to the effective weed management implemented during critical crop-weed competition periods.

Number of effective tillers hill^{-1}

The nitrogen levels had a considerable impact on the quantity of productive tillers hill^{-1}. The maximum count of productive tillers hill^{-1} (7.51) was obtained with a nitrogen application rate of 50 kg ha^{-1} and the lowest count (6.66) was obtained with a nitrogen

Table 5. Effect of weeding regime on crop characters, yield components and yield of fine rice (cv. BRRI dhan34).

Weeding regime	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Grains panicle^{-1} (no)	1000- grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
W_1	148.36a	7.77c	6.42c	121.6b	17.71c	9.26c	38.33c
W_2	148.14ab	8.75a	7.62a	128.1a	20.23a	10.19a	40.27a
W_3	143.56b	8.19b	6.94b	125.1ab	19.32b	9.62b	39.14b
Sx$^-$	1.25	0.059	0.071	1.33	0.265	0.043	0.198
Sig. level	*	**	**	**	**	**	**
CV (%)	2.58	2.14	3.03	3.19	4.17	1.36	1.51

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant; W_1 = one hand weeding at 15 DAT; W_2 = Two hand weeding at 15 and 30 DAT; W_3 = Three hand weeding at 15, 30 and 45 DAT.

Table 6. Interaction effects of level of nitrogen and weeding regime on crop characters, yield components and yield of fine rice (cv. BRRI dhan34).

Interaction effect	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Grains panicle^{-1} (no)	1000- grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
$N_1 \times W_1$	149.92	7.83 cd	6.66c	126.3	18.42	9.33 d	38.39 c
$N_1 \times W_2$	145.83	9.25 a	8.33a	129.8	20.89	10.76 a	40.54 a
$N_1 \times W_3$	147.42	8.67 b	7.53b	127.9	19.77	9.85 b	40.29 a
$N_2 \times W_1$	148.58	7.75 cd	6.45cd	121.9	17.53	9.24 d	38.31 c
$N_2 \times W_2$	145.83	8.50 b	7.30b	129.2	20.00	9.92 b	40.36 a
$N_2 \times W_3$	141.50	8.00 c	6.73c	123.7	19.39	9.57 c	39.09 bc
$N_3 \times W_1$	146.58	7.57 d	6.17d	116.4	17.18	9.23 d	38.30 c
$N_3 \times W_2$	143.75	8.50 b	7.25b	125.5	19.81	9.87 b	39.91 ab
$N_3 \times W_3$	141.75	7.92 c	6.58c	123.6	18.80	9.45 cd	38.05 c
Sx$^-$	2.17	0.102	0.123	2.30	0.459	0.075	0.343
Sig. level	NS	*	*	NS	NS	**	NS
CV (%)	2.58	2.14	3.03	3.19	4.17	1.36	1.51

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant; N_1 = 50 N kg ha^{-1}; N_2 = 100 N kg ha^{-1}; N_3 = 150 N kg ha^{-1}; W_1 = one hand weeding at 15 DAT; W_2 = Two hand weeding at 15 and 30 DAT; W_3 = Three hand weeding at 15, 30 and 45 DAT.

application rate of 150 kg ha^{-1} (Table 4). The number of productive tillers hill^{-1}(7.62) increased the most when weeding with two hands at 15 and 30 DAT and decreased while weeding with one hand at 15 DAT (Table 5). Additionally, the quantity of productive tillers hill^{-1}was strongly impacted by the interplay of nitrogen levels and weeding practices. The results showed that using two weeding at 15 and 30 DAT along with 50 kg of nitrogen per hectare led to the maximum count of fruitful tillers hill^{-1} (8.33). However, utilizing one-handed weeding at 15 DAT and 150 kg of nitrogen per acre resulted in the lowest count (6.17) (Table 6). Given the high costs involved in using hand weeding as the only weed control technique in aerobic rice systems; it would be preferable to include hand weeding as part of a more comprehensive weed management strategy. In comparison to only utilizing pesticides Singh *et al.* (2007) shows that this integrated technique not only significantly minimizes weed interference but also virtually doubles rice yields by boosting productive tillers. As a result, manual weeding is more cost-effective when used in conjunction with other methods, and it also performs better at controlling weeds.

Number of grains panicle^{-1}

Different nitrogen dosages caused a noticeable fluctuation in the number of grains panicle^{-1}. In particular, the application of 50 kg of nitrogen ha^{-1} resulted in the highest numerical count of grains panicle^{-1} (128.0) and was comparable to the count at 100 kg N ha $^{-1}$. On the other hand, while employing 150 kg N ha^{-1} the lowest count of grains panicle^{-1} (121.8) was observed and this count statistically mirrored that of 100 kg N ha^{-1} (Table 4). Additionally, the weeding schedule caused a statistically significant change in the amount of grains panicle^{-1}. As shown in (Table 5), the two weeding treatments applied at 15 and 30 DAT) resulted in the highest grain count panicle^{-1} (128.1), whereas the single hand weeding application at 15 DAT resulted in the lowest grain count per panicle (121.6). A noteworthy finding was that the interaction between the nitrogen level and the weeding schedule had no statistically significant impact on the number of grains panicle^{-1}. With two weeding at 15 and 30 DAT and 50 kg N ha^{-1}, the highest grains panicle^{-1} (129.8) was noted. The lowest count (116.4), on the other hand, was achieved at 15 DAT with one handed weeding and 150 kg N ha^{-1} (Table 6). This observation is consistent with those made in earlier research by Sarkar *et al.* (2017).

1000-grain weight

The amount of nitrogen presents significantly affected the weight of 1000 grains. While the lowest 1000-grain weight (18.59 g) was recorded when 150 kg N ha^{-1} was used, the highest 1000-grain weight (19.69 g) was seen when 50 kg N ha^{-1} was used which was equal to the weight attained with 100 kg N ha^{-1} (Table 4). The 1000 grain weight was strongly influenced by the weeding schedule. At 15 and 30 DAT, two rounds of hand weeding produced the maximum weight of 1000 grains (20.23 g), while just one cycle at 15 DAT produced the lowest weight (17.71 g) (Table 5). There was no discernible influence from the interplay of nitrogen levels and weeding practices. When two rounds of hand weeding were done at 15 and 30 DAT in addition to 50 kg N ha^{-1}, the maximum 1000-grain weight (20.89 g) was attained. However, one hand weeding cycle at 15 DAT with 150 kg N ha^{-1} applied resulted in the lowest 1000-grain weight (17.18 g) (Table 6). According to the statement, nitrogen's presence influenced the crop in a way that helped grains flourish. To be more precise, it helped the grains become plumper, which implies they were more completely formed and had superior overall size and shape. There was an increase in the total weight of grains produced as a result of this better grain growth (Jisan *et al.*, 2014; Pal *et al.*, 2016; Chowdhury *et al.*, 2016; Paul *et al.*, 2020)

Grain yield

Grain yield was significantly affected by nitrogen levels. Application of 50 kg N ha^{-1} resulted in the highest grain production (3.97 t ha^{-1}), which was comparable to the output from 100 kg N ha^{-1}. In contrast, applying 150 kg N ha^{-1} resulted in the lowest grain yield (3.69 t ha^{-1}) (Figure 3). A statistically significant relationship existed between the weeding schedule and grain yield (Figure 3). The two-hand weeding at 15 and 30 days after transplanting (DAT) produced the maximum grain yield (4.10 t ha^{-1}), while the single hand weeding at 15 DAT produced the lowest grain yield (3.55 t ha^{-1}). The more effective tillers per hill and grains per panicle in the two-hand weeding procedure are likely responsible for the enhanced grain output. Additionally, the nitrogen-weeding combination had a considerable impact on grain output. Two hand weeding at 15 and 30 DAT in addition to 50 kg N ha^{-1} were used to provide the maximum grain yield (4.36 t ha^{-1}). In contrast, utilizing one hand weeding at 15 DAT and 150 kg N ha^{-1} resulted in the lowest grain production (3.53 t ha^{-1}) (Figure 3). Alam *et al.* (2014) reported that the application of a two-hand weeding approach resulted in the highest rice grain yield. Similar result was recorded by Malek, (2008) who found that the maximum grain yield was obtained by conducting two rounds of weeding at 15 and 30 DAT, whereas the lowest yield was produced when no weeding was done. According to Neelam & Nisha, (2000), the seed production increased significantly linearly up to 80 kg N ha^{-1} and when fertilized with 120 kg N ha^{-1}, they found a modest decline in seed production.

Straw yield

Nitrogen concentrations have a substantial impact on straw output. Up to 50 kg N ha^{-1} of nitrogen was shown to boost the production of straw. The maximum yield of straw (6.01 t ha^{-1}) and the lowest yield (5.81 t ha^{-1}) were both obtained with 50 kg of nitrogen per hectare (Figure 4). The degree of weeding has a statistically significant impact on straw output. The results showed that two hand weeding at 15 and 30 DAT produced the best straw yield (6.08 t ha^{-1}), whereas one hand weeding at 15 DAT produced the lowest yield (5.71 t ha^{-1}) (Figure 4). The interplay between nitrogen level and weeding practices had a big impact on straw output. The lowest straw yield (5.69 t ha^{-1}) was observed in one hand weeding at 15 DAT with 150 kg N ha^{-1}, whereas the maximum straw yield (6.40 t ha^{-1}) was reported in two hand weeding at 15 and 30 DAT with 50 kg N ha^{-1} (Figure 4). The amount of straw produced was increased as a result of nitrogen's effects on the height and number of tillers hill^{-1}. Similar findings were found by Sarker (2012) who documented that a two-hand weeding method resulted in the most rice straw.

Biological yield

On the biological yield, nitrogen level had a considerable impact. 50 kg N ha^{-1} had the largest biological yield (9.98 t ha^{-1}). In 150 kg N ha^{-1}, the lowest biological production (9.51t ha^{-1}) was discovered (Table 4). The biological yield was statistically significantly affected by the weeding regimen. The two-hand weeding at 15 and 30 DAT produced the maximum biological output (10.19 t ha^{-1}), while the one hand weeding at 15 DAT produced the lowest biological yield (9.26 t ha^{-1}) (Table 5). The connection between the nitrogen level and the weeding strategy statistically affected biological yield. In a combination of two hand weeding at 15 and 30 DAT with 50 kg N ha^{-1}, the maximum biological yield (10.76 t ha^{-1}) was discovered. Using one hand weeding at 15 DAT and 150 kg N ha^{-1}, the lowest biological output was recorded (9.23 t ha^{-1}) (Table 6). Results that Ahmed *et al.* (2005) observed were in line with the conclusions being explored.

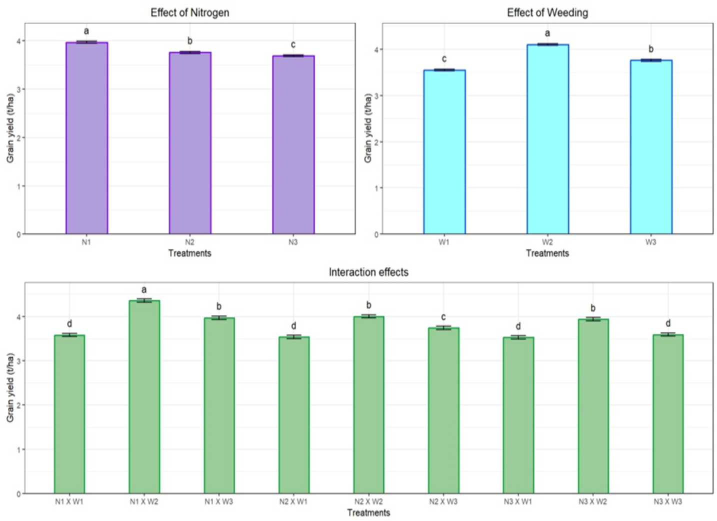

Figure 3. *Effect of level of nitrogen, weeding regime and their interactions on grain yield at different days after transplanting, Here,* N_1 *= 50 N kg ha*$^{-1}$*;* N_2 *= 100 N kg ha*$^{-1}$*;* N_3 *= 150 N kg ha*$^{-1}$*;* W_1 *= one hand weeding at 15 DAT;* W_2 *= Two hand weeding at 15 and 30 DAT;* W_3 *= Three hand weeding at 15, 30 and 45 DAT.*

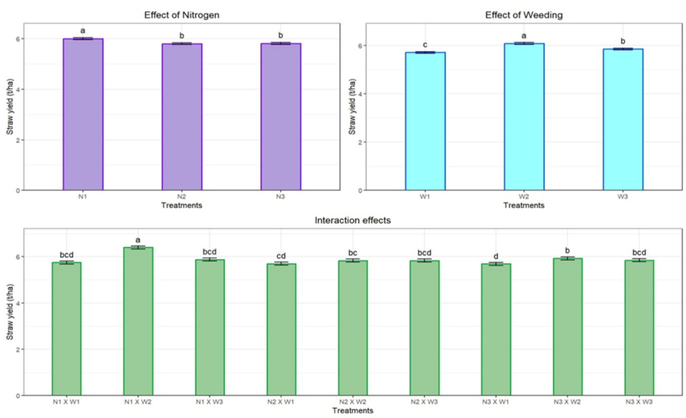

Figure 4. *Effect of level of nitrogen, weeding regime and their interactions on straw yield at different days after transplanting, Here,* N_1 *= 50 N kg ha*$^{-1}$*;* N_2 *= 100 N kg ha*$^{-1}$*;* N_3 *= 150 N kg ha*$^{-1}$*;* W_1 *= one hand weeding at 15 DAT;* W_2 *= Two hand weeding at 15 and 30 DAT;* W_3 *= Three hand weeding at 15, 30 and 45 DAT.*

Harvest index

The harvest index was significantly impacted by the nitrogen dosage. 50 kg N ha^{-1} had the greatest harvest index (39.74%), whereas 150 kg N ha^{-1} had the lowest harvest index (38.75%) (Table 4). The harvest index was significantly impacted by the weeding regimen. The two hand weeding operations at 15 and 30 DAT produced the greatest harvest index (40.27%), whereas the one hand weeding operations at 15 DAT produced the lowest harvest index (38.33%) (Table 5). The relationship between nitrogen level and weeding strategy did not significantly affect harvest index. In two weeding operations at 15 and 30 DAT with 50 kg N ha^{-1}, the greatest harvest index (40.54%) was discovered. With three hand weeding at 15, 30 and 45 DAT along with 150 kg N ha^{-1}, the lowest harvest index (38.05%) was discovered (Table 6). Similar findings were reported by Khatun *et al.* (2023) and Sarkar *et al.* (2017).

Conclusion

The results of this experiment demonstrate the yield of fragrant fine rice (BRRI dhan34) significantly influenced by nitrogen management and weed control technique. Two times hand weeding at 15 and 30 DAT in addition to the application of 50 kg of nitrogen ha^{-1} has shown to be a highly successful and promising strategy in terms of growth and productivity. This holistic approach helps reduce weed competition, enhances nutrient availability for rice plants and improves crop productivity. These insights offer valuable guidance to rice farmers and agricultural professionals, contributing to a practical and sustainable strategy for increasing the yield of fragrant fine rice.

DECLARATIONS

Author's contribution

Conceptualization, methodology: M.S. and S.K.P; validation: S.K.P. and S.K.S.; Investigation: M.S., S.K.P. and M.H.R; Data curation: M.F.H., S.K.S. and F.M.J.U; Writing -original draft preparation: M.S.K. and M.F.H.; Writing-review and editing: S.K.P., M.H.R. and F.M.J.U; Supervision: M.S., and S.K.P. All authors have read and agreed to the published version of the manuscript.

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