Archives of Agriculture and Environmental Science 8(2): 182-190 (2023)
https://doi.org/10.26832/24566632.2023.0802014

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes

ORIGINAL RESEARCH ARTICLE

Influence of seedling age and integrated nutrient management on growth and yield of aromatic rice (cv. BRRI dhan34)

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ARTICLE HISTORY

Received: 02 April 2023
Revised received: 18 June 2023
Accepted: 21 June 2023

Keywords

BRRI dhan34
Growth
Integrated nutrient management
Seedling age
Yield

ABSTRACT

To investigate the performance of aromatic rice (cv. BRRI dhan34) in response to seedling age and nutrient management, an experiment was carried out at the Sher-e-Bangla Agricultural University, Dhaka from July to December 2021. The experiment includes three different ages of seedlings to be transplanted viz., 30, 45 and 60 days old and six nutrient management practice viz. control (no manures and fertilizers), recommended dose of inorganic fertilizers (RDF), 50% of RDF + cow dung @ 5 t ha^{-1}, 75% of RDF + cow dung @ 5 t ha^{-1}, 50% of RDF + poultry manure @ 2.5 t ha^{-1} and, 75% of RDF + poultry manure @ 2.5 t ha^{-1}. The experiment was laid out in a randomized complete block design with three replications. The results revealed that in the case of transplanting of different aged seedlings, the highest leaf area index (5.74), dry matter hill^{-1} (32.86 g), number of tillers hill^{-1} (13.17), number of effective tillers hill^{-1} (11.53), plant height (113.34 cm), total grains panicle^{-1} (135.14), 1000-grain weight (12.45 g), grain yield (3.29 t ha^{-1}), straw yield (4.01 t ha^{-1}), biological yield (7.30 t ha^{-1}) and were recorded from transplanting 30 days old seedlings. Different levels of nutrient management showed a significant impact on most of the parameters under study. The highest total dry matter hill^{-1} (34.02 g), the maximum LAI (5.35), plant height (115.70 cm), chlorophyll content (42.87), number of effective tillers hill^{-1} (12.99), panicle length (24.63 cm), total grains panicle^{-1} (140.17), 1000-grain weight (12.54 g), grain yield (3.27 t ha^{-1}), straw yield (4.15 t ha^{-1}), biological yield (7.42 t ha^{-1}) and harvest index (43.03%) were also recorded in F5 (75% of RDF + poultry manure @ 2.5 t ha^{-1}) treatment. While considering the interaction effects between the age of seedlings and nutrient management, transplanting 30 days old seedlings along with the nutrient management of 75% of RDF + poultry manure @ 2.5 t ha^{-1} treatment improved yield contributing parameters and provided the highest yield (3.76 t ha^{-1}) of BRRI dhan34 compared to other treatment combination. So, the application of 75% of RDF + poultry manure @ 2.5 t ha^{-1} along with 30 days old seedlings appeared as a promising practice to obtain better performance of fine aromatic rice (cv. BRRI dhan34).

Citation of this article: Sabil, A. S., Haque, M. M., Ahamed, K. U., Hasan, M. R., Paul, N. C., & Mahamud, M. A. (2023). Influence of seedling age and integrated nutrient management on growth and yield of aromatic rice (cv. BRRI dhan34). *Archives of Agriculture and Environmental Science*, *8*(2), 182-190, https://dx.doi.org/10.26832/24566632.2023.0802014

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop grown all over the world and serves as the main staple food for more than half of the world's population (Marzia and Najnine, 2022). Since ancient times, different varieties of rice are favored by various civilizations. Aromatic rice is popular in Asian countries but nowadays they are becoming more popular in Europe and the

United States (Kabir *et al.*, 2020). Due to a shift in consumer behavior for higher quality rice during the past two decades, the demand for fragrant rice has grown intensely. As a result, farmers have switched to high-yielding modern varieties because of the higher yield which compensates for the premium price of scented rice (Kumar *et al.*, 2017). According to Sarkar *et al.* (2014), Bangladesh has excellent prospects for exporting aromatic rice, which would generate foreign currency. A variety of high-quality scented rice varieties are grown by Bangladeshi farmers. Among the most popular kinds are Chinisagar, Badshabhog, Kataribhog, Kalizira, Tulsimla, Dulabhog, Basmati, BRRI dhan50 (Banglamoti), BRRI dhan34, BRRI dhan37, BRRI dhan38, and Binadhan-13 (Laila *et al.*, 2022). Among all BRRI released aromatic rice varieties BRRI dhan34 is the most cultivated one in Bangladesh (Marzia and Najnine, 2022).

The age of seedlings is an important factor for a consistent stand of rice and to control its development and productivity (Sinha *et al.*, 2018). Sometimes in Bangladesh, the transplanting of Aman rice is postponed due to the late recession of flood water and the unavailability of seedlings (Roy *et al.*, 2018). In these situations, more seedlings can be produced in the nursery bed and transplanted into the main field at a later time than is ideal, for reducing flood damage (Luna *et al.*, 2017). On the other hand, Mobasser *et al.* (2007) observed that, when seedlings spend more time in the nursery beds, the major tiller buds on the lower nodes of the main culm degenerate, which results in less tiller output. For rice to grow in a consistent stand, the age of the seedling upon transplanting is a key component (Amin and Haque, 2009; Faghani *et al.*, 2011).

Despite having year-round ideal agroclimatic conditions for rice cultivation, the average national output of grain in Bangladesh is somewhat lower than that of other nations that also produce rice (Marzia and Najnine, 2022). According to several research, factors such as nutrient mining, soil organic matter depletion, reduction in soil aggregates, and others have been implicated as causes of yield stagnation and loss of agricultural productivity (Sohel *et al.*, 2016; Mahamud *et al.*, 2022). The factors contributing to poor yield also include unwise nutrient management (Nila *et al.*, 2018). Although chemical fertilizers are crucial for providing plants with the nutrients they need, their persistent nature is a larger danger to sustainable agriculture (Tyagi and Singh, 2019). Contrarily, organic manures such as cow dung or poultry manure not only provide nutrients to plants but also enhance the physical, chemical, and biological qualities of soil (Paul *et al.*, 2021). In the modern intensive agricultural system, neither organic manures nor chemical fertilizers by themselves could produce yield sustainability at a high level. Therefore, for sustainable agriculture and to ensure food production with high quality it is necessary to the combined use of organic and inorganic sources of nutrients (Mahmud *et al.*, 2016).

The ideal seedling age and adequate nutrient management are essential components of cultivation techniques, and their adjustment may improve growth, development, and yield, while also lowering the production cost of aromatic rice. Numerous research studies have been conducted on aromatic rice varieties, but little is known about how seedling age and nutrition management affect the production of aromatic rice. Considering the above facts, the current study was undertaken to determine how the age of seedlings at staggered transplanting and nutrient management affected the performance of aromatic rice yield performance (*cv*. BRRI dhan34).

MATERIALS AND METHODS

Experimental site and experimentation

An experiment was conducted at the Sher-e-Bangla Agricultural University's experimental field. (23.077' N latitude, 90.035' E longitude, and 8.2 meters above sea level), Dhaka, during the period of July, 2021 to December, 2021 to study the effect of age of seedlings and nutrient management on crop characters, yield component, and yield of BRRI dhan34. The soil of the experimental field belonged to "The Madhupur Tract", AEZ-28 (FAO, 1998). The soil was sandy loam with organic matter of 1.15%, 26% sand, 43% silt, and 31% clay. The test site was a highland area with a pH of 5.6.

The experimental treatments consisted of three levels of age of seedlings viz., 30 days old seedlings, 45 days old seedlings and 60 days old seedlings and, six type of nutrient management viz. Control (no manures and fertilizers), recommended dose of inorganic fertilizers (RDF), 50% of RDF + cow-dung @ 5 t ha^{-1}, 75% of RDF+ cow-dung @ 5 t ha^{-1}, 50% of RDF + poultry manure @ 2.5 t ha^{-1} and 75% of RDF + poultry manure @ 2.5 t ha^{-1}. The total numbers of unit plots were 54. The size of each unit plot was 4.0 m × 2.5 m. Two-unit plots and two blocks were spaced by 0.5 m and 1.0 m, respectively.

Crop husbandry

Seeds of BRRI dhan34 were collected from BRRI (Bangladesh Rice Research Institute), Gazipur just 20 days ahead of the sowing of seeds in the seed bed. On July 26, 2021, the sprouted seeds were uniformly spread on the beds according to the treatment combination. The specified amount of cow-dung, poultry manure, recommended inorganic fertilizer were applied at final land preparation except urea. Urea was applied in three equal splits, at 15, 35, and 50 days after transplanting (DAT). The recommended dose of fertilizers was 150, 97, 70, 60, and 12 kg ha^{-1} urea, TSP, MoP, gypsum, and zinc sulphate, respectively (Sarkar *et al.*, 2014). All management practices were done as and when necessary.

Data collection on growth traits

The data on different crop characters were collected both at vegetative and in maturity stage. To record data on growth parameters, leaf area was manually estimated by measuring the length and width of the leaf and multiplying by a factor of 0.75.

$$\text{Leaf area index} = \frac{\text{Surface area of leaf sample (cm}^2\text{)} \times \text{Correction factor}}{\text{The ground area from where the leaves were collected (cm}^2\text{)}}$$

To determine chlorophyll content, flag leaves SPAD values were recorded at 7 days after flowering (DAF) using chlorophyll meter from each plot. To determine the total dry matter, the segmented plant samples were kept in separate envelopes and were oven dried at 70°C for 72 hours. Following drying, the weight of each sample was calculated using a digital balance to establish the mean. Finally, total dry matter (TDM) was calculated by adding the weight of different plant parts. At maturity, from each unit plot five hills were taken randomly to record yield contributing attributes and the entire plots were harvested to obtain grain and straw yields. The harvested crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. The grain from the manually threshed harvested crops was washed, and it was then dried to a moisture level of 14%. Straws were carefully sun-dried. Final grain and straw yields plot^{-1} were recorded and converted to t ha^{-1}. The harvest index was calculated as follows:

$$\text{Biological yield} = \text{Grain yield} + \text{Straw yield}$$

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (t ha}^{-1})}{\text{Biological yield (t ha}^{-1})} \times 100$$

Statistical analysis of data

The analysis of variance of all the recorded parameters was performed according to the procedure outlined by Gomez and Gomez (1984), using the MSTAT-C version 2.1 (Michigan State University, USA) statistical package design software. The difference of the means value was separated by the Least Significance Difference (LSD) test at 5% level of probability.

RESULTS AND DISCUSSION

Growth characters

Leaf area index (LAI): LAI was significantly affected by the age of seedlings, and nutrient management (Table 1 and 2). The highest leaf area index (5.74 cm) was found from 30 days old seedlings and the lowest (4.37) was from 45 days old seedlings which was statistically similar to (4.13) recorded from 60 days old seedlings (Table 1). The age of seedlings has a significant influence on leaf area index and leaf area decreased with the increased seedling age reported elsewhere (Luna *et al*., 2017 and Roy *et al*., 2018). Different forms of nutrient management have a significant variation in the LAI of BRRI dhan34. Table 1 also showed that, the highest leaf area index (5.35 cm) was observed with 75% of RDF + poultry manure @ 2.5 t ha^{-1} treatment, which was statistically similar to F_3 75% of RDF+ cow-dung @ 5 t ha^{-1}. Meanwhile, the lowest (4.16) was obtained from control i.e., no manures and fertilizers which was statistically similar to 50% of RDF + cow-dung @ 2.5 t ha^{-1}) and RDF (Table 1). Correspondingly, Nila *et al.* (2018) stated that, the application of 25% less than the recommended dose of inorganic fertilizers + poultry manure @ 2.5 t ha^{-1},resulted in better photosynthetic translocations, accumulation, and the highest leaf area index. The highest LAI (6.88) was attained from 30 days old seedling along with 75% of RDF along with poultry manure @ 2.5 t ha^{-1} treatment, while, the lowest LAI value (3.74) was found from the 60 days old seedling along with no manures and fertilizers (Table 2).

Chlorophyll content (SPAD value): Chlorophyll content was significantly affected by different levels of the age of seedlings, nutrient content and their interactions (Table 1 and 2). The highest chlorophyll content (39.66) was found from 45 days old seedlings which was statistically similar to (39.52) recorded from 30 days old seedlings and the lowest (37.89) was from 60 days old seedlings (Table 1). The results of the present investigation were consistent with those of Pramanik and Bera (2013). They conclude that, younger seedlings produce more chlorophyll than older seedlings because young seedlings can endure transplant shock better than older seedlings. Table 1 showed that, the highest chlorophyll content (42.87) was observed with 75% of RDF + poultry manure @ 2.5 t ha^{-1} treatment. On the other hand, the lowest (35.27) was obtained from control i.e., no manures and fertilizers (Table 1). Likewise, Sarker *et al.* (2015) observed that, significantly higher chlorophyll "a" and chlorophyll "b" was recorded in 100% inorganic fertilizer poultry manure @ 5 ton ha^{-1}. This increment of chlorophyll might have resulted in better photosynthetic translocations, accumulation, and ultimately increased yield of rice. The highest chlorophyll content (43.84) was attained from 30 days old seedling) along with 75% of RDF + poultry manure @ 2.5 t ha^{-1}treatment, which is at par with 45 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1}. The lowest chlorophyll content value (34.31) was found from the 30 days old seedling along with no manures and fertilizers which was at par with 60 days old seedling along with no manures and fertilizers (Table 2).

Total dry matter hill^{-1}: The age of seedlings, nutrient management and their interactions significantly affects the total dry matter at 1% level of probability (Table 1 and 2). The highest total dry matter (32.86 g hill^{-1}) was found in 30 days old seedlings and the lowest total dry matter 30.92 g hill^{-1} was found in 60 days old seedlings (Table 1). Delay in transplanting results in a concomitant reduction in dry matter production of seedlings and longer stay of seedlings in the seedbed affects seedling growth pattern in response to high seedling competition matter production as compared to the use of older seedlings of 45 and 60 days age old seedlings. Sinha *et al.* (2018) noticed that, planting younger seedlings of 30 days of age led to a significant increase in dry matter. Similarly, the maximum total dry matter (34.02 g hill^{-1}) was recorded in treatment 75% of RDF + poultry manure @ 2.5 t ha^{-1} and minimum total dry matter (29.82 g hill^{-1}) was recorded in treatment no manures and fertilizers (Table 1). This might be explained by the availability of enough nutrients throughout the growth phase, which leads to improved uptake and superior product characteristics such as total dry matter. Results of the current study were in consent with several findings elsewhere (Kundu *et al*., 2016, Mahata *et al*., 2019; Nila *et al*., 2018 and Marzia and Najnine, 2022), they concluded that,

Table 1. Effect of age of seedlings and nutrient management on leaf area index, chlorophyll content and total dry matter of aromatic rice BRRI dhan34.

Seedling age	Leaf area index	Chlorophyll content (SPAD value)	Total dry matter (g hill^{-1})
S_1	5.74 a	39.52a	32.86a
S_2	4.37 b	39.66a	32.42b
S_3	4.13 b	37.89b	30.92c
Level of significance	**	**	**
CV (%)	8.01	1.59	0.69
Nutrient management			
F_0	4.16 c	35.27d	29.82e
F_1	4.49 c	37.80c	31.52c
F_2	4.41 c	37.42c	30.61d
F_3	5.11 ab	40.41b	33.08b
F_4	4.96 b	40.36b	33.35b
F_5	5.35 a	42.87a	34.02a
Level of significance	**	**	**
CV (%)	8.01	1.59	0.69

In a column, values having the same letters under each treatment do not differ significantly whereas values with dissimilar letters differ significantly as per LSD. ** = Significant at 1% level of probability. Note: S1 = 30 days old seedlings, S2 = 45 days old seedlings and S3 = 60 days old seedlings; F_0 = Control (no manures and fertilizers), F_1 = Recommended dose of inorganic fertilizers (RDF), F_2 = 50% of RDF + cow-dung @ 5 t ha^{-1}, F_3 = 75% of RDF+ cow-dung @ 5 t ha^{-1}, F_4 = 50% of RDF + poultry manure @ 2.5 t ha^{-1}, F_5 = 75% of RDF + poultry manure @ 2.5 t ha^{-1}.

Table 2. Effect of interaction between age of seedlings and nutrient management on leaf area index, chlorophyll content and total dry matter of aromatic rice BRRI dhan34.

Interaction effect	Leaf area index	Chlorophyll content (SPAD value)	Total dry matter (g hill^{-1})
S_1F_0	4.74cd	34.31i	30.33ij
S_1F_1	5.18c	37.74f	32.25d-g
S_1F_2	5.03c	38.15ef	30.30j
S_1F_3	5.88b	41.88b	34.04c
S_1F_4	6.74a	41.24bc	34.58bc
S_1F_5	6.88a	43.84a	35.65a
S_2F_0	4.00e	36.21gh	30.80hij
S_2F_1	4.28de	38.99de	31.61e-h
S_2F_2	4.05e	38.09ef	31.26g-j
S_2F_3	4.69cd	40.59c	32.87d
S_2F_4	4.16de	40.64c	32.87d
S_2F_5	5.01c	43.41a	35.08ab
S_3F_0	3.74e	35.28hi	28.33k
S_3F_1	4.01e	36.66g	30.71hij
S_3F_2	4.14de	36.03gh	30.26j
S_3F_3	4.76cd	38.76def	32.33def
S_3F_4	3.97e	39.21d	32.59de
S_3F_5	4.15de	41.36bc	31.33f-i
Level of significance	**	**	**
CV (%)	8.01	1.59	0.69

In a column, values having the same letters under each treatment do not differ significantly whereas values with dissimilar letters differ significantly as per LSD. ** = Significant at 1% level of probability. Note: S_1 = 30 days old seedlings, S_2 = 45 days old seedlings and S_3 = 60 days old seedlings. F_0 = Control (no manures and fertilizers), F_1 = Recommended dose of inorganic fertilizers (RDF), F_2 = 50% of RDF + cow-dung @ 5 t ha^{-1}, F_3 = 75% of RDF+ cow-dung @ 5 t ha^{-1}, F_4 = 50% of RDF + poultry manure @ 2.5 t ha^{-1}, F_5 = 75% of RDF + poultry manure @ 2.5 t ha^{-1}.

nutrient management had a significant influence on total dry matter content of rice. Furthermore, the highest total dry matter was found (35.65 g hill^{-1}) from interaction 30 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1}, while the lowest total dry matter number of effective tillers was found 28.33 g hill^{-1} in interaction 60 days old seedling along with no manures and fertilizers (Table 2). Similarly, Adhikari *et al.* (2013) and Roy *et al.* (2020) also found significant variation in total dry matter content and suggested that, the reasons for differences in total dry matter content might be due to the interaction between the age of seedlings and nutrient management.

Yield and yield contributing characters

Plant height: Plant height is one of the important crop characteristics. Plant height was significantly influenced by age of seedlings, nutrient management and their interactions at a 1% level of probability (Table 3 and 4). Plant height decreased significantly with the age of seedlings. The tallest plant (113.34 cm) was recorded as 30 days old seedling which is significantly higher than 45 days old seedling (110.63 cm) and 60 days old seedling (109.65 cm) (Table 3). The findings of the current study were consistent with those of Pramanik and Bera (2013), who suggested that, earlier transplanting of seedlings may increase

Table 3. Effect of age of seedlings and nutrient management on yield and yield contributing characters of aromatic rice BRRI dhan34.

Seedling age	Plant height (cm)	No. of tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000-grain weight (gm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_1	113.34a	13.17a	11.53a	1.64a	21.15b	135.14a	12.45a	3.29a	4.01a	7.30a	45.02a
S_2	110.63b	11.99b	10.52b	1.48b	20.07c	134.19a	11.45b	2.90b	3.95b	6.85b	42.24b
S_3	109.65c	10.98c	09.23c	1.76a	21.66a	128.43b	11.04c	2.57c	3.77c	6.34c	40.53c
Level of significance	**	**	**	*	**	**	**	**	**	**	**
CV (%)	0.91	4.46	5.98	14.42	3.51	1.10	2.83	2.07	1.88	1.47	1.48
Nutrient management											
F_0	107.35d	10.13d	7.94e	2.20a	17.20e	123.49f	10.74d	2.60e	3.64e	6.24e	43.03c
F_1	109.48c	11.63c	9.88d	1.74b	19.89d	131.93d	11.32c	2.80c	3.84c	6.64c	41.98c
F_2	109.31c	11.63c	10.17cd	1.46c	20.79c	127.39e	11.16c	2.71d	3.73d	6.44d	41.60c
F_3	112.81b	12.62b	10.91b	1.73b	21.25c	137.36b	12.00b	3.06b	4.03b	7.09b	42.03b
F_4	112.60b	11.99c	10.66bc	1.33c	21.99b	135.16c	12.13b	3.09b	4.07b	7.15b	43.03b
F_5	115.70a	14.29a	12.99a	1.30c	24.63a	140.17a	12.54a	3.27a	4.15a	7.42a	43.03a
Level of significance	**	**	**	**	**	**	**	**	**	**	**
CV (%)	0.91	4.46	5.98	14.42	3.51	1.10	2.83	2.07	1.88	1.47	1.48

In a column, values having the same letters under each treatment do not differ significantly whereas values with dissimilar letters differ significantly as per LSD. ** = Significant at 1% level of probability. Note: Note: S_1 = 30 days old seedlings, S_2 = 45 days old seedlings and S_3 = 60 days old seedlings F_0 = Control (no manures and fertilizers), F_1 = Recommended dose of inorganic fertilizers (RDF), F_2 = 50% of RDF + cow-dung @ 5 t ha^{-1}, F_3 = 75% of RDF+ cow-dung @ 5 t ha^{-1}, F_4 = 50% of RDF + poultry manure @ 2.5 t ha^{-1}, F_5 = 75% of RDF + poultry manure @ 2.5 t ha^{-1}.

plant height due to greater vigor, root development, and decreased transplant shock caused by lower leaf area during the early stages of crop growth, which stimulates increased cell division and increases stem elongation. Likewise, Amin and Haque (2009) also stated that, 35 days old seedlings performed better than 15, 25, and 45 days old seedlings in terms of plant height. Considering nutrient management the tallest plant (115.70 cm) was found with 75% of RDF + poultry manure @ 2.5 t ha^{-1} and the shortest plant (107.35 cm) was obtained from control treatment (no manures and fertilizers) (Table 3). A similar result was also observed by Mahata *et al.* (2019); Marzia and Najnine (2022), and Laila *et al.* (2022). They reported that, plant height significantly differs from the source of nutrients and found integrated nutrients more effective than sole organic or inorganic fertilizer. Again, considering interactions the tallest plant (118.07 cm) was recorded from 30 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1} and the shortest plant (105.98 cm) was obtained from 60 days old seedling along with no manure and no fertilizer, which was statistically similar with (106.97 cm) recorded from 60 days old seedlings along with recommended dose of inorganic fertilizers (Table 4). Adhikari *et al.* (2013) also stated that, the age of seedlings and nutrient management has a significant relationship on the plant height of rice.

Number of tillers hill^{-1}: The results of the present study showed that, the number of tillers hill^{-1} differed significantly due to the age of seedlings, nutrient management and their interaction effect at 1% level of probability (Table 3 and 4). The highest number of tillers hill^{-1}(13.17) was recorded from 30 days old seedlings followed by 45 days old seedlings (11.99) and the lowest number of tillers hill^{-1}(10.98) was obtained from 60 days old seedlings. However, younger seedlings produced more tillers than older seedlings, which may be related to reduce root damage since younger seedlings were better able to establish them after being transplanted in the main field. The current study's findings were in line with those of Krishna *et al.* (2009); Faghani *et al.* (2011) and Roy *et al.* (2018) who found that, transplanting very young seedlings typically results in stronger tillering and roots, which affects the hill^{-1} tillering number. Considering nutrient management, the highest number of tillers hill^{-1} (14.29) was recorded with 75% of RDF + poultry manure @ 2.5 t ha^{-1}. On the other hand, the lowest number of tillers hill^{-1} (10.13) was obtained from control treatment (Table 3). These findings were also supported by other researchers in different rice cultivars (Laila *et al.*, 2022; Marzia and Najnine, 2022 and Nila *et al.*, 2018). They reported that, the combined application of organic and inorganic fertilizer increased the accessibility of major and minor nutrients to the plant. This may have boosted early root growth and cell division, which then increased the absorption of other nutrients from deeper soil layers, increasing the number of tillers hill^{-1}. However, in view of interaction effect, the highest number of tillers hill^{-1}(16.22) was recorded with 30 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1} and the lowest number of tillers hill^{-1} (9.91) was obtained from 30 days old seedling along with no manures and fertilizers treatment (Table 4). The interaction effect between seedling age and nutrient management had a significant influence on the number of tillers hill^{-1}was also reported elsewhere (Adhikari *et al.*, 2013; Roy *et al.*, 2018 and Roy *et al.*, 2020).

Table 4. Effect of interaction between age of seedlings and nutrient management on yield and yield contributing characters of aromatic rice BRRI dhan34.

Interaction effect	Plant height (cm)	No. of tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000-grain weight (gm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_1F_0	108.16fg	9.91i	7.82j	2.08b	18.25h	125.12kl	11.04gh	2.90f	3.70ij	6.60de	43.96de
S_1F_1	112.73c	12.74d	10.79cde	1.95bcd	20.33g	132.56g	11.84cde	3.17d	3.93d-g	7.11c	44.64bcd
S_1F_2	110.17e	11.79ef	10.73cde	1.06i	20.29g	127.00ijk	12.00cd	2.95ef	3.70j	6.64de	44.36cd
S_1F_3	115.72b	14.67b	12.80b	1.87b-e	22.13d	141.39b	12.96b	3.45b	4.15c	7.60b	45.42ab
S_1F_4	115.20b	13.70c	12.28b	1.42f-i	20.18g	137.05de	13.10b	3.51b	4.22bc	7.72b	45.40abc
S_1F_5	118.07a	16.22a	14.74a	1.49e-h	25.72a	147.69a	13.76a	3.76a	4.35a	8.10a	46.35a
S_2F_0	107.92fg	10.01i	8.15ij	1.86b-e	15.26i	123.54lm	10.93gh	2.63 h	3.76hij	6.38fg	41.15gh
S_2F_1	108.74f	11.68ef	9.99def	1.69c-f	17.37h	135.56ef	11.20fg	2.74 g	3.86e-h	6.59de	41.54g
S_2F_2	107.43g	12.48de	11.20c	1.27ghi	20.16g	129.40hi	10.91gh	2.68 gh	3.81g-j	6.50ef	41.32gh
S_2F_3	111.29de	11.75ef	10.17def	1.58d-g	20.72fg	138.30cd	11.62def	3.02e	4.01d	7.03c	42.94ef
S_2F_4	112.31cd	11.53fg	10.35c-f	1.18hi	22.30cd	138.89cd	11.85cde	3.01e	4.01d	7.02c	42.87f
S_2F_5	116.07b	14.54bc	13.27b	1.27ghi	24.61ab	139.47bc	12.22c	3.31c	4.28ab	7.59b	43.62def
S_3F_0	105.98h	10.50i	7.85ij	2.64a	18.10h	121.80m	10.26i	2.27 j	3.46k	5.73i	39.68j
S_3F_1	106.97gh	10.45i	8.86ghi	1.59d-g	21.96de	127.68hij	10.90gh	2.49 i	3.74hij	6.23gh	39.92ij
S_3F_2	110.31e	10.62hi	8.57hij	2.05bc	21.92def	125.77jkl	10.56hi	2.49i	3.69j	6.18h	40.28hij
S_3F_3	111.42de	11.50fgh	9.76efg	1.74b-f	20.90efg	132.41g	11.43efg	2.71 gh	3.94def	6.65de	40.74ghi
S_3F_4	110.28e	10.72ghi	9.34fgh	1.38f-i	23.50bc	129.55h	11.43efg	2.74g	3.97de	6.72d	40.82ghi
S_3F_5	112.96c	12.12def	10.96cd	1.16hi	23.57b	133.36fg	11.65def	2.74 g	3.82f-i	6.56de	41.74g
Level of significance	**	**	*	*	**	**	*	**	**	**	*
CV (%)	0.91	4.46	5.98	14.42	3.51	1.10	2.83	2.07	1.88	1.47	1.48

In a column, values having the same letters under each treatment do not differ significantly whereas values with dissimilar letters differ significantly as per LSD. ** = Significant at 1% level of probability, * = Significant at 5% level of probability. Note: S_1 = 30 days old seedlings, S_2 = 45 days old seedlings and S_3 = 60 days old seedlings. F_0 = Control (no manures and fertilizers), F_1 = Recommended dose of inorganic fertilizers (RDF), F_2 = 50% of RDF + cow-dung @ 5 t ha^{-1}, F_3 = 75% of RDF+ cow-dung @ 5 t ha^{-1}, F_4 = 50% of RDF + poultry manure @ 2.5 t ha^{-1}, F_5 = 75% of RDF + poultry manure @ 2.5 t ha^{-1}.

Number of effective tillers hill^{-1}: The age of seedlings, nutrient management and their interaction significantly affects the number of effective tillers hill^{-1} at 1% level of probability (Table 3 and 4). The highest average number of effective tillers hill^{-1} (11.53) was found in 30 days old seedlings followed by 45 days old seedlings and the lowest number of effective tillers hill^{-1} (9.23) was found in 60 days old seedlings (Table 3). According to Sultana *et al.* (2020), the growth, yield, and yield-contributing traits such as chlorophyll content of transplant rice were significantly influenced by the age of the seedling, nitrogen levels, and their interactions. According to Luna *et al.* (2017) seedlings that were 30 days old produced more productive tillers than those that were 45 and 60 days old. However, the highest number of effective tiller hill^{-1} (12.99) was recorded in treatment 75% of RDF + poultry manure @ 2.5 t ha^{-1} and the lowest number of effective tiller hill^{-1} (7.94) were recorded in control treatment (Table 3). Likewise, Sohel *et al.* (2016) observed that, the highest number of effective tillers hill^{-1} was obtained in the treatment of cow-dung + poultry manure + water hyacinth + fertilizer. In view of interaction effect of age of seedlings and nutrient management the highest effective tillers hill^{-1} (14.74) was found in interaction 30 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1} while the lowest number of effective tillers was found (7.82) in interaction 30 days old seedling with control treatment (Table 4). Similarly, Roy *et al.* (2020) concluded that, optimum seedling age and efficient nutrient management results in a higher number of effective tillers hill^{-1}.

Number of non-effective tillers hill^{-1}: Present results showed that, the number of non-effective tillers hill^{-1} was significantly influenced by seedling age, nutrient management and their interactions (Table 3 and 4). The highest number of non-effective tillers hill^{-1} (1.76) was found in the case of 60 days old seedlings which were statistically similar to 30 days old seedlings (Table 3). Results of the study are in accordance with Luna *et al.* (2017), where they stated that, 30 days old seedlings provide the lowest number of non-effective tillers than 45, and 60 days old seedlings which results into better growth, and yield, of aromatic rice. Nutrient management significantly influenced the number of non-effective tillers hill^{-1} at 5% level of probability (Table 3). The lowest non-effective tillers hill^{-1} was (1.30) found in the treatment 75% of RDF + poultry manure @ 2.5 t ha^{-1} and the highest non-effective tillers hill^{-1} was (2.20) resulting from no manures and fertilizers (Table 3). Results were also supported by several other studies (Sarkar *et al.*, 2014; Roy *et al.*, 2017 and Roy *et al.*, 2020). This might be explained by the non availability of enough nutrients throughout the growth phase, which leads the production of higher non-effective tillers hil^{-1} and superior production characteristics. While observing the interaction effect of age of seedlings and nutrient management the lowest number of non-effective tillers hill^{-1} (1.06) was obtained from the treatment combination of 30 days old seedling along with 50% of RDF + cow-dung @ 2.5 t ha^{-1} and the highest number of non-effective tillers hill^{-1} (2.64) was found in interactions of 60 days old seedling along with (no manures and fertilizers) (Table 4). Roy *et al.* (2018); and Roy *et al.* (2020) observed the interaction of seedling age and nutrient management having similar kinds of results in rice.

Panicle length: Panicle length is one of the important crop characteristics that determine the yield of crops. In the experiment panicle length was significantly influenced by age of seedlings, nutrient management and their interaction at 1% level of probability (Table 3 and 4). The highest length of panicle (21.66 cm) was recorded at 60 days old seedlings which are followed by 30 day old seedlings (21.15 cm) (Table 3). Luna *et al.* (2017) from their study concluded that, the longest panicle was observed with transplanting of 25 days old seedlings as compared to 35 days old seedlings. Again, the longest panicle length (24.63 cm) was found in 75% of RDF + poultry manure @ 2.5 t ha^{-1} and the shortest panicle length (17.20 cm) was obtained from control treatment (no manures and fertilizers) (Table 3). Similar results were also observed by Sohel *et al.* (2016) and Roy *et al.* (2018). They reported that, the combination of organic and inorganic fertilizers was found to be more efficient in increasing the panicle length of rice. Considering the interaction between seedling age and nutrient management, results revealed that, the longest panicle length (25.72 cm) was recorded from 30 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1} which was at par with 45 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1}. On contrary, the shortest panicle length which was statistically similar to (4.37 cm) recorded from 45 days old seedlings (15.26 cm) was obtained from 45 days old seedling along with no manures and fertilizers (Table 4). Roy *et al.* (2018) also found significant variation in panicle length and suggested that, the reasons for differences in panicle length might be due to the interaction between the age of seedlings and nutrient management.

Number of grains panicle^{-1}: The number of grains panicle^{-1} was significantly affected by different levels of the age of seedlings and nutrient management (Table 3 and 4). The highest number of grains panicle^{-1} (135.14) was found from 30 days old seedlings, which was statistically similar to 30 days old seedlings (Table 3). Luna *et al.* (2017) also found that, the number of filled grains panicle^{-1} decreased with the increasing age of seedlings. Different forms of nutrient management have a significant variation in BRRI dhan34. Table 3 showed that, the highest number of grains panicle^{-1} (140.17) was observed with 75% of RDF + poultry manure @ 2.5 t ha^{-1} treatment (Table 3). This might be explained by the availability of enough nutrients throughout the growth phase, which leads to improved uptake and superior production characteristics. Kumar *et al.* (2017) and Kundu *et al.* (2016) reported that, the number of grains panicle^{-1} varied significantly among the different sources of nutrients. Again, when the interaction effect was taken into account, the highest number of grains panicle^{-1} (147.69) was attained from 30 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1} treatment, which is at par with 30 days old seedling along with 50% of RDF + poultry manure @ 2.5 t ha^{-1} (Table 4). In a study, Adhikari *et al.* (2013) observed that, the interaction effect between age of seedlings and nutrient management had a significant influence on the number of filled grain panicle^{-1}.

Weight of 1000-grains: The weight of 1000-grain was significantly influenced by age of seedlings, nutrient management and their interactions (Table 3 and 4). The highest 1000-grain weight (12.45 gm) was recorded at 30 days old seedlings (Table 3). The findings of Faghani *et al.* (2011) stated that, the optimum timing of transplanting led to a greater 1000-grain weight, which was consistent with the results of the current investigation. The change in 1000-grain weight with seedling age might be explained by the fact that seedlings transplanted into the field at a young age showed little to no root damage, higher solar radiation absorption, and greater nutrient uptake than the older seedlings. However, considering nutrient management the highest 1000-grain weight (12.54 gm) was found with 75% of RDF + poultry manure @ 2.5 t ha^{-1} and the lowest 1000-grain weight (10.74 gm) was obtained from control treatment (Table 3). In a similar study, Teli *et al.* (2018); Mahata *et al.* (2019) and Islam *et al.* (2021b) found that, various combinations of organic manures and inorganic fertilizers had a significant effect on the 1000-grain weight of rice. Considering the interaction between seedling age and nutrient management, results revealed that, the highest 1000-grain weight (13.76 gm) was recorded from 30 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1} and the lowest 1000-grain weight (10.26 gm) was obtained from 60 days old seedling along with no manures and fertilizers (Table 4). According to Roy *et al.* (2018), the interaction between seedling age and nutrient management led to considerable variations in 1000-grain weight. They observed that, 30 days old seedling with 75% of RDF + poultry manure @ 2.5 t ha^{-1} provided the highest 1000-grain weight in BRRI dhan38.

Grain yield: Grain yield was significantly affected by different levels of the age of seedlings, nutrient management (Tables 3 and 4). The highest grain yield (3.29 t ha^{-1}) was found from 30 days old seedlings and the lowest (2.57 t ha^{-1}) was from 60 days old seedlings (Table 3). Early transplants of seedlings may have benefited from the weather and environment through better development of the upper ground plant and the below-ground roots. The outcome of the current investigation was consistent with other studies (Faghani *et al.*, 2011; Reuben *et al.*, 2016 and Virk *et al.*, 2020). Similarly, Luna *et al.* (2017) reported that, 30 days old seedlings performed better and had significantly higher yield potential than those of 45 days and 60 days old seedlings. Again, Table 3 showed that, the highest grain yield (3.27 t ha^{-1}) was observed with 75% of RDF + poultry manure @ 2.5 t ha^{-1} treatment. Meanwhile, the lowest grain yield (2.60 t ha^{-1}) was obtained from control i.e., no manures and fertilizers. The increased yield attributes and yield might be due to the increased supply of the macro and micronutrients under the influence of sources of inorganic nutrients. According to Roy *et al.* (2017) application of 75% of the recommended dose of inorganic fertilizers + poultry manure @ 2.5 t ha^{-1} showed superiority in terms of the highest grain yield (5.56 t ha^{-1}). The interaction effect of seedling age and nutrient management showed the highest grain yield (3.76 t ha^{-1}) was attained from 30 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1} treatment. The lowest grain yield (2.27 t ha^{-1}) was found from the 60 days old seedling along with no manures and fertilizers (Table 4). The results of the current study agreed with those of Adhikari *et al.* (2013) and Roy *et al.* (2018).

Straw yield: The effect of seedling age, nutrient management significantly influenced the straw yield of rice at 1% level of probability (Table 3 and 4). The highest straw yield (4.01 t ha^{-1}) was found in treatment 30 days old seedling and the lowest straw yield (3.77 t ha^{-1}) was observed in 60 days old seedling (Table 3). Bagheri *et al.* (2011) noticed that, the highest straw yield was obtained from 20 days old seedlings over 30 and 40 days. Luna *et al.* (2017) stated that, younger seedlings produced significantly higher straw (5.17 t ha^{-1}) yields as compared to older seedlings from their studies on aromatic rice. Again, the foremost straw yield (4.15 t ha^{-1}) was found with 75% of RDF + poultry manure @ 2.5 t ha^{-1} and the lowest straw yield (3.64 t ha^{-1}) was obtained from control treatment which was statistically significant with Recommended dose of inorganic fertilizers (Table 3). Nutrient management has a significant influence on straw yield and straw yield increased with the integrated use of organic and inorganic sources of nutrients were reported elsewhere (Sarkar *et al.*, 2014; Sohel *et al.*, 2016; Naher and Paul, 2017; and Teli *et al.*, 2018). As the interaction between seedling age and nutrient management, the maximum value of straw yield (4.35 t ha^{-1}) was recorded from 30 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1} which was statistically similar to 45 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1} (Table 4). The outcome of the current investigation was consistent with other studies (Faghani *et al.*, 2011; Reuben *et al.*, 2016 and Virk *et al.*, 2020).

Biological yield: The biological yield was significantly influenced by age of seedlings, nutrient management and their interaction at 1% level of probability (Table 3 and 4). The highest biological yield (7.30 t ha^{-1}) was recorded at 30 days old seedling which is significantly higher than 45 days old seedlings (6.85 t ha^{-1}) and 60 days old seedlings (6.34 t ha^{-1}) (Table 3). The result obtained from the present study was similar with the findings of Islam *et al.* (2021a) and reported that, the highest biological yield (9.23 t ha^{-1}) was obtained from 30 days old seedlings. Chakrabortty (2013) reported that, seedling age varied the biological yield of rice under SRI. Meanwhile, the highest biological yield (7.42 t ha^{-1}) was found with 75% of RDF + poultry manure @ 2.5 t ha^{-1} and the lowest biological yield (6.24 t ha^{-1}) was obtained from control treatment (Table 3). Similarly, Roy *et al.* (2018) stated that, the application of 25% less than the recommended dose of inorganic fertilizers + poultry manure @ 2.5 t ha^{-1}, resulted into better photosynthetic translocations, accumulation, and assimilation which resulted into higher biological yield of rice. Since, the interaction between seedling age and nutrient management, the highest biological yield (8.10 t ha^{-1}) was recorded from 30 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1} and the lowest biological yield (5.73 t ha^{-1}) was obtained from 60 days old seedling) along with no manures and fertilizers (Table 4). Adhikari *et al.* (2013) and Roy *et al.* (2018) also stated that, the age of seedlings and nutrient management has a significant relationship with the plant height of rice.

Harvest index: The harvest index is one of the important yields contributing parameters. In the experiment harvest index was significantly influenced by age of seedlings at 1% level of probability (Table 3). The maximum harvest index (45.02%) was recorded at 30 days old seedling which is followed by 45 days old seedling (42.24%). On the other hand, the lowest harvest index was observed at 60 days old seedlings (40.53%) (Table 3). The result obtained from the present study was similar to the findings of Islam *et al.* (2021a) and reported that, the highest harvest index was obtained from younger seedlings. Also, the highest harvest index (43.03%) was found in 75% of RDF + poultry manure @ 2.5 t ha^{-1} and the lowest harvest index (41.60%) was obtained from treatment 50% of RDF + Cow-dung @ 5 t ha^{-1} (Table 3). Teli *et al.* (2018); and Islam *et al.* (2021b) stated that, the harvest index is significantly influenced by nutrient management. Also, Roy *et al.* (2017) showed that, harvest index was significantly influenced by fertilizer management. The application of 75% of the recommended dose of inorganic fertilizers + poultry manure @ 2.5 t ha^{-1} showed superiority in terms of the highest harvest index (47.05%). Considering the interaction between seedling age and nutrient management, the highest harvest index (46.35%) was recorded from 30 days old seedling along with 75% of RDF + poultry manure @ 2.5 t ha^{-1}. On contrary, the lowest harvest index (39.68%) was obtained from 60 days old seedling along with no manures and fertilizers which (Table 4).

Conclusion

The present study showed that seedling age and nutrient management has significant influence on yield and yield contributing characters of aromatic rice. Older seedlings decreased plant growth and yield irrespective of nutrient management. In this experiment, 30 days old seedlings gave 28.01% more yield than transplanting 60 days old seedlings. In the case of nutrient management, 75% of RDF + poultry manure @ 2.5 t ha^{-1} gave the highest 1000 grains weight, grain yield, straw yield, biological yield and harvest index. Combined interaction of 30 days old seedlings and 75% of RDF + poultry manure @ 2.5 t ha^{-1} are suitable for getting higher yield from BRRI dhan34 in *Aman* season. Furthermore, it has been suggested that, studies of similar nature could be carried out in different agroecological zones (AEZ) of Bangladesh for the evaluation of zonal adaptability.

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