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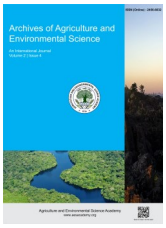

ORIGINAL RESEARCH ARTICLE

Performance of Purple rice cultivar under different hill density

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ABSTRACT

Purple rice has become a fascinating source of nutritional value among healthy cereal grains. A field experiment was conducted at Bangladesh Agricultural University during the *Rabi* season (February to May) of 2021 to evaluate the effect of number of seedlings/hill on growth, yield attributes and yield of Purple rice. Three seedling densities, *viz*. 1, 2 and 3 seedlings/hill, and three rice cultivars, *viz*. Purple rice, Pahari rice and a check BRRI dhan67 were experimental treatments and the experiment was laid out in a split-plot design with three replications. Results revealed that seedling number/hill had significant effects on the growth, yield and yield attributes of rice cultivars. The tallest plant (136.31 cm) was observed from the transplanting of 1 seedling/hill followed by 2 seedlings/hill (133.35 cm) in Pahari rice. The maximum values of the number of effective tillers (13.47; Purple rice), flag leaf length and width (41.36 and 1.24 cm; Pahari rice) were recorded from the treatment 2 seedlings/hill. The longest panicle (26.58 cm; Pahari rice) was observed in 1 seedling/hill, statistically, a similar value was found with 2 seedlings/hill (24.44 cm). Among rice cultivars, BRRI dhan67 produced the heaviest grains (1000-seed weight 23.96 g) with 2 seedlings/hill and maximum grain yield (6.35 t/ha) with 1 seedling/hill. Single seedling/hill was found to be the best management practice to get a higher yield per unit area for Purple rice and other rice cultivars also.

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INTRODUCTION

A rare rice cultivar, Purple rice, is now drawing the attention of the progressive farmers and researchers of Bangladesh for its exceptional leaf and stem colour. This rice possesses many traditional uses, for example, curing skin diseases (Ujjawal, 2016); stopping diarrhoea and bleeding after childbirth, as healthy food, cooked by mixing with white rice (Kim, 2015); consumed on special occasions and for brewing alcoholic beverages (Schiller *et al*., 2006). Discoveries of various phytochemical compounds have led to rising interest in purple rice as a highly valued, functional food with potential health benefits to consumers (Veni, 2019). This rice is rich in anthocyanin and has high antioxidant properties (Jang and Xu, 2009). Antioxidative and anti-inflammatory activities have been ascribed as the key properties of anthocyanin in the prevention of chronic diseases, such as cancer (Hui *et al*., 2010), diabetes, and cardiovascular disease (Wallace, 2011; Sancho and Pastore, 2012), etc. The high amount of anthocyanin in leaf tissues also allows the plant to develop resistance against several environmental stresses (Eryilmaz, 2006; Kielkowska *et al*., 2019) and ultimately helps in increased production in the changing climatic situation.

Rice grain yield is a function of several factors such as the number of total and effective tillers/m^2, spikelets/panicle, (filled and) ripened grains and 1000-grain weight, although, grain weight and the number of spikelets/panicle are mostly genetically controlled characters (Yoshida, 1981). Agronomic management practices, for example, through manipulating the number of seedlings/hill might play an important role in regulating the number of tillers/unit area ultimately influencing the plant growth, panicle density and grain yield in rice (Verma *et al*., 2002; Alam *et al*., 2012; Rasool *et al*., 2012; Ullah *et al*.,

2015; Devi *et al.*, 2019; Promsomboon, 2019; Singh *et al.*, 2020). The larger number of seedlings/hill increases competition for tiller formation, solar radiation interception, sunshine reception, nutrient uptake, photosynthesis rate and other physiological phenomena which eventually affect the growth and development of plants (Bozorgi *et al.*, 2011). On contrary, a lesser number of seedlings/hill may cause an insufficient tiller number, thus keeping space and nutrients underutilized, resulting in lower grain yield. The optimum number of seedlings/hill is, therefore, found to be essential to facilitate the plant to grow properly. For the transplanting method, seedling age, seedlings/hill and spacing might affect rice yield and yield components differently for different cultivars.

Rice, the staple food of Bangladeshi people, is being cultivated in 11.42 million ha of land with a production of 36.6 million metric tons of grains in 2019-2020 (BBS, 2021). The population is expected to reach 215.4 million in 2050 (Kabir *et al.*, 2016), therefore, time demands to increase the production of rice to feed this ever-increasing population in Bangladesh. Proper use of our rice genetic resources as cultivar and/or breeding materials for high-yielding cultivars, and improving the management practices are necessary for increasing rice yield as well. The traditional Purple rice cultivar, being a potential functional food, can play a vital role in the nutritional security of Bangladesh. Although it is known to researchers long ago, the research-based recommendation for the production technology of this cultivar is scanty (Kuddus *et al.*, 2020; Nahar *et al.*, 2021). The aim of this study is, therefore, to evaluate and enhance the (grain) yield potentials of purple rice through the number of seedlings/hill management.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the Field Laboratory ($24^0$75′N $90^0$50′E; 18 m above sea level), Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, Bangladesh during the *Rabi* season (February to May) of 2021. The topography was medium-high belonging to the Sonatola soil series of grey flood plain soil type under the Agro-Ecological Zone-9 Old Brahmaputra Flood Plain (UNDP and FAO, 1988). The soil was silty loam and imperfectly to poorly drained. The monthly mean of daily maximum, minimum and mean temperature, relative humidity, total rainfall, air pressure, wind speed and sunshine hours during the cropping period were presented in Table 1.

Experimental design

Experimental treatments consisted of three hill densities, *viz.* 1, 2 and 3 seedlings/hill, and three rice cultivars, two traditional, *viz.* Purple rice and Pahari rice, and a modern check BRRI dhan67. The experiment was laid out in a split-plot design, with the number of seedlings/hill as the main plot factor and rice cultivars as the sub-plot factor, with three replications.

Crop husbandry

The seeds were sown in the seedbed on 25 December 2020. Transplanting of healthy seedlings was done on 3 February 2021. Forty days old rice seedlings were uprooted separately from the respective nursery and transplanted into the experimental plot as per the requirement of treatments maintaining 20 cm × 15 cm spacing (Kuddus *et al.*, 2020). The recommended dose of fertilizer for BRRI dhan67 was used for all the cultivars (BARC, 2018). The experimental plot (5 m^2) received a half dose of nitrogen (36 kg/ha), a full dose of phosphorus (11 kg/ha) and potassium (46 kg/ha) as basal application and the remaining half dose of nitrogen (36 kg/ha) was top-dressed at 30 DAT. All management practices were done as and when necessary.

Data collection

Five hills/plot were properly tagged for recording crop growth and yield attributes whereas the whole plot area was harvested to assess grain and straw yields. At harvest, data on growth and yield descriptors, *viz.* plant height, number of total, effective and non-effective tillers/hill, flag leaf length and width, panicle length, number and length of primary and secondary branches, filled and unfilled grains in primary & secondary branches and panicle, 1000-seed weight and seed yield were recorded.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using Statistix 10 to identify the main effects and interactions in response to seedling number/hill. Differences among means were determined using LSD at the 5% level of significance.

Table 1. Monthly average air pressure, temperature, relative humidity, total rainfall, wind speed and total sunshine from December 2020 to May 2021.

Months	Air pressure (mbs)	Air Temperature (°C)			Relative humidity (%)			Rainfall (mm)	Wind speed (km/h)	Sunshine (hrs)
		Max.	Min.	Mean	Max.	Min.	Avg.			
December	1012.1	24.8	13.6	19.2	98.7	58.2	86.1	0.0	1.26	4.8
January	1011.7	23.7	12.6	18.2	99.0	59.6	85.2	0.0	2.0	4.6
February	1010.8	28.4	15.2	21.8	96.6	42.4	75.6	0.0	2.4	7.0
March	1007.9	31.5	20.6	26.1	95.3	47.7	75.0	0.0	3.7	6.0
April	1006.2	33.7	22.7	28.2	92.7	52.5	75.2	1.5	5.2	7.8
May	1003.5	33.2	24.5	28.9	94.1	61.8	80.7	12.1	5.4	5.6

RESULTS AND DISCUSSION

Both seedlings/hill and cultivars significantly differed growth traits *viz.* plant height, length and width of flag leaf (Figures 1 and 2). The tallest plant (136.31 cm) was observed from the combination of Pahari rice and 1 seedling/hill; a statistically similar value (133.35 cm; Pahari rice) was also observed with 2 seedlings/hill. Purple rice with 3 seedlings/hill was recorded with the lowest plant height (97.54 cm) (Figure 1). Variation in plant height among cultivars might be due to the heredity or genetic make-up of a cultivar (BRRI, 2017). The plants, transplanted in 1 and 2 seedlings/hill treatments, might receive maximum exposure to sunlight during the growth period causing better photosynthesis and consequently resulting in a taller plant. Alam *et al.* (2012) and Promsomboon (2019) also found the highest plant height with 2 seedlings/hill; although, Islam and Salam (2017) reported no significant influence of seedling/hill on plant height. The short stature of the cultivar Purple rice might add additional value, resistance to lodging, compared to other rice cultivars.

The number of total and effective tillers/hill varied significantly among the cultivars, however, no significant difference was observed due to the number of seedlings/hill. The maximum number of effective tillers was recorded from 2 seedlings/hill (13.47) in Purple rice and the minimum from 3 seedlings/hill (9.87) in Pahari rice (Table 2). Alam *et al.* (2012) also found no significant influence of seedlings/hill on the number of effective tillers/hill, though he recorded a higher number of effective tillers with 2 seedlings/hill. Islam and Salam (2017) also got the same result. The higher number of seedlings per unit area decreases the availability of soil nutrients, which affects plant growth (Li *et al.*, 2013; Ullah *et al.*, 2015). The long and broad flag leaves were found in Pahari rice with 2 seedlings/hill (41.36 cm and 1.24 cm, respectively) while the short (23.09 cm; Purple rice) and narrow (1.03 cm; BRRI dhan67) ones were found with 3 seedlings/hill (Figure 2; Table 2).

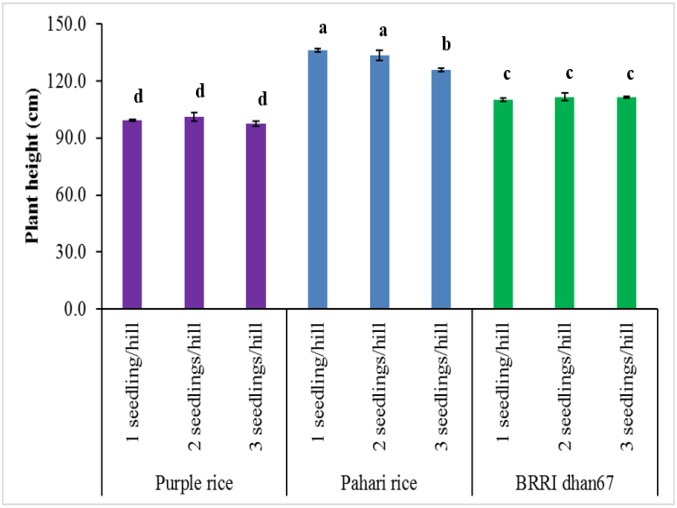

Figure 1. *Interaction effect of seedlings/hill and cultivars on plant height of rice. Vertical bars indicate the standard error (±) of the mean (n=3).*

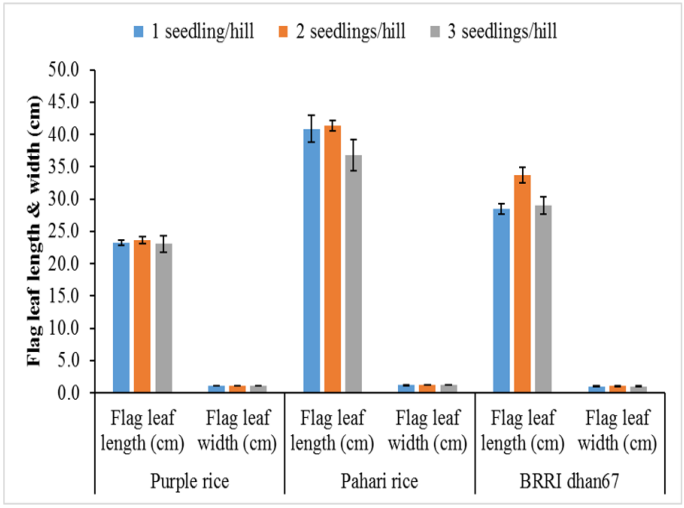

Figure 2. *Interaction effect of seedlings/hill and cultivars on flag leaf length and width of rice. Vertical bars indicate the standard error (±) of the mean (n=3).*

Table 2. Tillering habit and flag leaf traits of rice cultivars as influenced by seedlings/hill.

Cultivar	Treatment	Total tiller (no.)	Effective tiller (no.)	Non-effective tiller (no.)	Flag leaf length (cm)	Flag leaf width (cm)
Purple rice	1 seedling/hill	12.80	11.53 ab	1.27	23.25 d	1.06 bc
	2 seedlings/hill	14.13	13.47 a	0.67	23.66 d	1.15 ab
	3 seedlings/hill	13.93	12.47 ab	1.47	23.09 d	1.06 bc
Pahari rice	1 seedling/hill	11.20	10.27 ab	0.93	40.86 a	1.17 a
	2 seedlings/hill	11.52	10.38 ab	1.13	41.36 a	1.24 a
	3 seedlings/hill	11.47	9.87 b	1.60	36.81 ab	1.23 a
BRRI dhan67	1 seedling/hill	13.13	12.33 ab	0.80	28.49 cd	1.03 c
	2 seedlings/hill	12.60	11.47 ab	1.13	33.69 bc	1.04 c
	3 seedlings/hill	13.80	12.67 ab	1.13	29.03 cd	1.03 c
$LSD_{0.05}$		3.13	3.29	1.22	***	***
Level of significance	Variety	**	**	ns	*	*
	Treatment	ns	ns	ns	ns	ns
	Variety × Treatment	ns	ns	ns	6.62	0.10

All values given are means of three replicates. *, ** and ***, significant at 5%, 1% and 0.1% level of significance, respectively. ns, non-significant. In a column, figures bearing dissimilar letter differ significantly at 5% level of significance.

Table 3. Panicle structure and yield attributing traits of rice cultivars as influenced by seedling (no.)/hill. 1^0 Primary, 2^0 Secondary.

Cultivar	Treatment	Panicle length (cm)	1^0 branch / panicle (no.)	2^0 branch / panicle (no.)	1^0 branch length (cm)	2^0 branch length (cm)	Filled grains/ 2^0 branch (no.)	Unfilled grains/2^0 branch (no.)	Filled grains/ 1^0 branch (no.)	Unfilled grains/1^0 branch (no.)	Filled grains / Panicle (no.)	Unfilled grains / Panicle (no.)	1000-grain weight (g)
Purple rice	1 seedling/hill	24.12 b	10.33 a	27.73 ab	10.82 c	3.22 c	1.30 c	3.00 ab	11.93 bc	6.97 a	99.83 a-c	53.40 b	22.47 c
	2 seedlings/hill	23.85 b	10.37 a	26.17 ab	10.60 c	3.19 c	0.90 c	3.37 a	10.10 c	8.73 a	79.43 c	67.37 a	22.04 c
	3 seedlings/hill	23.57 b	9.73 ab	23.10 b	11.11 c	3.22 c	1.53 c	2.93 ab	11.40 bc	7.13 a	85.00 bc	49.97 bc	23.11 b
Pahari rice	1 seedling/hill	26.58 a	9.33 bc	30.33 ab	13.65 a	3.84 ab	1.97 bc	3.50 a	13.37 a-c	8.33 a	91.03 a-c	75.63 a	21.27 d
	2 seedlings/hill	24.17 b	8.80 c	33.07 a	13.36 ab	4.26 ab	4.40 a	1.73 b-d	18.93 a	5.63 ab	124.13 a	42.63 c	20.61 e
	3 seedlings/hill	23.23 b	8.73 c	30.70 ab	12.33 b	3.70 bc	3.63 ab	1.97 bc	16.73 ab	5.23 a-c	107.77 a-c	51.37 bc	20.28 e
BRRI dhan67	1 seedling/hill	24.07 b	9.37 bc	25.07 b	13.18 ab	4.35 a	3.83 ab	0.90 cd	15.80 a-c	2.93 b-d	116.77 a-c	20.57 d	22.19 c
	2 seedlings/hill	24.44 ab	8.90 c	25.00 b	13.09 ab	4.27 ab	4.03 a	0.70 cd	15.60 a-c	1.67 cd	119.20 ab	14.77 d	23.96 a
	3 seedlings/hill	23.76 b	9.03 c	23.87 b	12.98 ab	4.14 ab	3.97 a	0.50 d	16.47 ab	1.40 d	118.50 ab	11.27 d	23.37 b
$LSD_{0.05}$		2.20	0.68	7.88	1.21	0.62	1.98	1.30	5.84	3.66	3.66	9.93	0.47
Level of significance	Cultivar	ns	***	***	***	***	***	***	***	***	***	***	***
	Treatment	**	**	ns	ns	ns	ns	*	ns	ns	ns	***	**
	Cultivar × Treatment	*	ns	ns	*	ns	*	**	ns	ns	*	***	***

All values given are means of three replicates. *, ** and ***, significant at 5%, 1% and 0.1% level of significance, respectively. ns, non-significant. In a column, figures bearing dissimilar letter differ significantly at 5% level of significance.

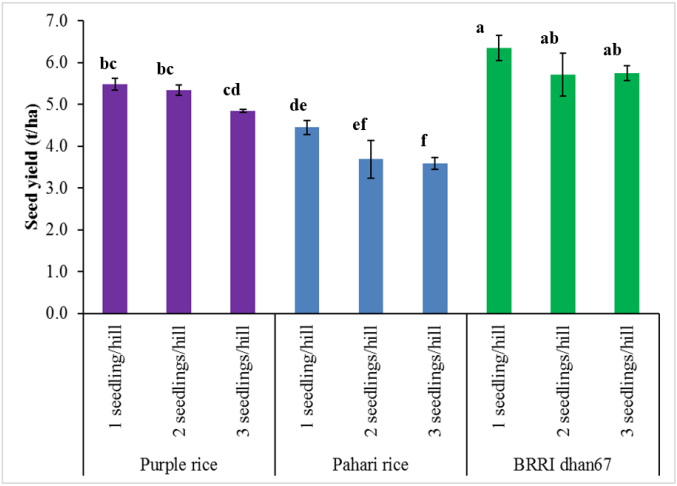

Figure 3. *Interaction effect of seedlings/hill and cultivars on seed yield of rice. Vertical bars indicate the standard error (±) of mean (n=3).*

Panicle length differed significantly only due to the variation in seedlings/hill (Table 3). The longest panicle (26.58 cm) was observed with 1 seedling/hill and a statistically similar value was recorded from 2 seedlings/hill (24.44 cm) whereas, 3 seedlings/hill produced the shortest panicle (23.23 cm). Lesser number of seedlings/hill might increase the panicle length through maximum exposure to nutrients, moisture and sunlight (Alam *et al.* 2012). On contrary, Faruk *et al.* (2009) reported no significant effect on panicle length due to seedlings/hill. Both cultivar and seedlings/hill had a significant effect on the number of primary branch/panicle ranging from 8.73 to 10.37 (Table 3). The maximum value was recorded from 2 seedlings/hill in Purple rice while the minimum was from 3 seedlings/hill in Pahari rice.

The number of secondary branches/panicle, length of primary and secondary branches, number of filled grain in primary & secondary branches and panicles differed significantly only due to variety (Table 3). These traits might mostly be genetically controlled, the environment has little/no effect on these (Sarwar and Ali, 1998). The longest primary branch was observed in Pahari rice (13.65 cm) and the shortest in Purple rice (10.60 cm). The maximum number (33.07) and longest (4.35 cm) secondary branch were observed in Pahari rice and BRRI dhan67, respectively. The maximum number of filled grains in primary & secondary branches and panicles were recorded in Pahari rice (18.93, 4.40 and 124.13 respectively; 2 seedlings/hill). Single seedling/hill produced a maximum number of unfilled grain/panicle (75.63) in Pahari rice and a statistically similar value was found with 2 seedlings/hill (67.37) in Purple rice whereas, the lowest values (11.27 and 14.77) were found with 3 and 2 seedlings/hill in BRRI dhan67 (Table 3). Variations in the number and length of primary and secondary branches on the rachis of different cultivars were also reported by Sarwar and Ali (1998), Faruk *et al.* (2009), Alam *et al.* (2012), and Kuddus *et al.* (2020).

The BRRI dhan67 produced the heaviest grain (1000-seed weight, 23.96 g) with 2 seedlings/hill and maximum grain yield (6.35 t/ha) with 1 seedlings/hill (Table 3 and Figure 3). Single seedling/hill was found to be a better treatment to get the highest yield per unit area. Similar results were also obtained by Baloch *et al.* (2006) and Islam and Salam (2017). It might be due to the higher values of panicle length, primary branches/panicle and 1000-grain yield, and lowest number of sterile spikelets/panicle (Table 3). Single seedling/hill could use up more nutrients than 2, 3 and 4 seedlings/hill, and it also had the benefit of low vegetative biomass in the initial growth stages (Baloch *et al.*, 2006). Moreover, the use of a higher number of seedlings/hill adds to (production) cost and mere wastage of natural resources as well. The minimum values for thousand seed weight and grain yield (20.28 g, 3.59 t/ha) were recorded from 3 seedlings/hill. When the planting densities exceed the optimum level, competition among plants becomes severe and conse-

quently, the plant growth slows down and the grain yield decreases. Although Faruk *et al*. (2009) reported that the seedling/hill significantly influenced grain yield without influencing thousand seed weight; two seedlings per hill gave higher grain yield.

Conclusion

The transplanting of a single seedling/hill was found to be better for growth and grain yield of both traditional *viz*. Purple rice and Pahari rice, and the modern BRRI dhan67(check) rice cultivars. Farmers might practise this transplanting method to ensure the proper growth and higher grain yield through the proper and economic management of Purple rice cultivars in Bangladesh.

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