Grain yield and quality of aromatic *Boro* rice (cv. BRRI dhan50) subject to date of transplanting and nutrient management

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ABSTRACT

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from December 2015 to May 2016 to find out the effect of date of transplanting and nutrient management on the yield and quality of aromatic *Boro* rice cv. BRRI dhan50. The experiment comprised five dates of transplanting, viz., 15 December, 30 December, 15 January, 30 January and 15 February, and four nutrient managements, viz., recommended dose of inorganic fertilizer (N, P, K, S and Zn at the rate of 115, 25, 60, 18, 3.5 kg ha^{-1}, respectively), poultry manure 5 t ha^{-1}, 25% less than the recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure, 50% less than the recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure. The experiment was laid out in a randomized complete block design with three replications. Crop characters, yield components, and yield quality were significantly influenced by date of transplanting, nutrient management and their interactions. The highest number of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$, grain yield and grain protein content were recorded when the crop was transplanted on 15 December. Yield components, grain yield and grain protein content gradually decreased due to delay in transplanting. In case of nutrient, the highest number of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$, 1000–grain weight, grain yield, grain protein content and aroma level were recorded when the crop was fertilized with 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure. Similarly, the highest grain yield was also recorded when fertilized with 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure and transplanted on 15 December 2015 which was at par with on 15 December 2015 transplanting and fertilized with the recommended dose of inorganic fertilizer. Early transplanting on 15 December 2015 and fertilization with 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure was found to be promising practice for the cultivation of BRRI dhan50 under Old Brahmaputra Floodplain Soils of Bangladesh.

Keywords: Rice, aroma, protein, manure, fertilizer

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INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for the people of Bangladesh. Aromatic rice contributes a small portion but an important subgroup of rice in Bangladesh. Currently, it has been introduced to the global market because of its taste, deliciousness and high price. Most of the scented rice varieties in Bangladesh are of the traditional type, photoperiod sensitive and cultivated during the Aman season (late summer) with lower yield compared to coarse and medium rice varieties. The *Boro* season (winter rice) aromatic rice cv. BRRI dhan50 (Banglamoti) developed by the Bangladesh Rice Research Institute (BRRI) has gained huge popularity among farmers for its fragrance and relatively high productivity. Generally, the grain yield of rice in *Boro* season is higher than that in Aman season due to the prevailing climatic condition among which the uninterrupted sunlight for the whole day is a notable one. Cultural practices are also responsible for grain yield and protein content of rice (Akram *et al*., 1985). The environment contributes to a larger portion of the total variability in protein content of rice. Plant density, type, mode and time of fertilizer application, water management, weeding and solar radiation can influence protein content (Gomez and De Datta, 1975).

Rice plants require a particular environment especially temperature for panicle initiation to maturity which mostly depends on its date of transplanting. Sometimes farmers are failed to transplant on time due to the main field is occupied by another crop. If rice transplanted on later than optimum time may be subject to heat damage during heading or grain filling period thus encourage sterility and resulting in low yields. Several researchers reported that early transplanting increased the grain yield of aromatic rice as compared to late planting (Mukesh *et al*., 2013; Islam *et al*., 2014). Rice yield is also associated with judicious nutrient management especially the integration of manure with inorganic fertilizers. The application of manure in soil stimulates microbial activity and mineralization of plant nutrients which ultimately increased soil fertility (Ferreras *et al*., 2006). Grain yield and protein content of fine aromatic rice increased significantly due to the application of 75% of recommended dose of inorganic fertilizers along with cowdung (Pal *et al*., 2016). The judicious application of nitrogen fertilizer may also improve grain yield and grain protein content in rice (Ray *et al*., 2015). Above discussion indicates that time of planting and nutrient management is very important to improve the yield and quality of aromatic *Boro* rice and there is enough scope to carry out research work on these important issues. Therefore, the present study was conducted to ascertain the suitable date of planting and nutrient management of grain yield and quality of aromatic *Boro* rice.

MATERIALS AND METHODS

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during the period from December 2015 to May 2016. The experimental site is located at 24.75°N latitude and 90.50°E longitude at an altitude of 18 m. The site belongs to the non–calcareous dark grey floodplain soil under the agro–ecological zone of the Old Brahmaputra Floodplain (AEZ–9; UNDP and FAO, 1988). The experimental plot is medium high land having sandy loam texture with pH 6.8, electrical conductivity (EC) 1.23 ds/m, organic carbon 1.29%, N 0.13%, P 13 ppm, K 0.24% meq, S 15 ppm, Zn 0.60 ppm and B 0.25 ppm. The experimental area is under the sub-tropical climate. The average monthly temperature (°C), relative humidity (%) and total rainfall (mm) prevailing at the experimental site during experimentation are presented in Figure 1.

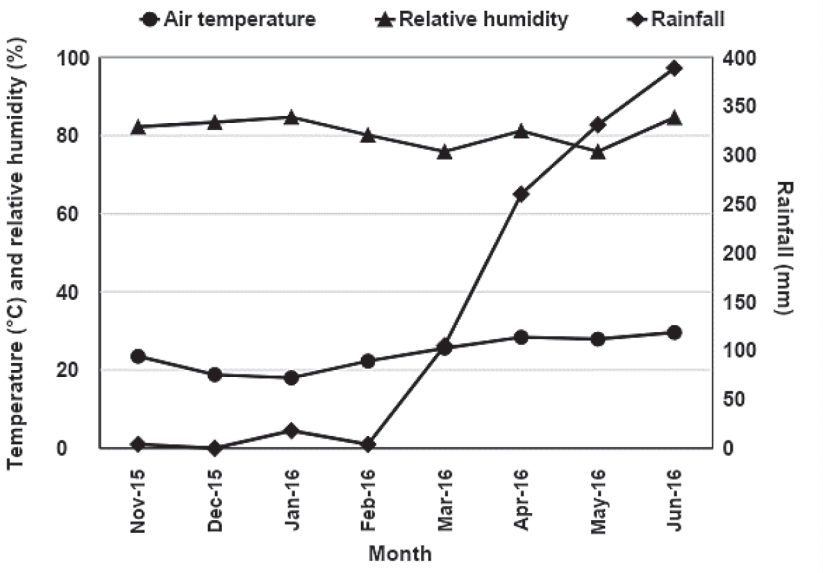

Figure 1 Temperature, relative humidity and rainfall condition in crop growing period

The BRRI dhan50 (Banglamoti), a modern aromatic fine rice variety, was used as the test crop. The average grain yield of BRRI dhan50 is 6.0–6.5 t ha^{-1}. The study consisted of five dates of transplanting which were 15 December 2015, 30 December 2015, 15 January 2016, 30 January 2016 and 15 February 2016 with four nutrient managements including the recommended dose of inorganic fertilizer (N, P, K, S and Zn at the rate of 115, 25, 60, 18, 3.5 kg ha^{-1}, respectively), poultry manure 5 t ha^{-1}, 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure and 50% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure. The experiment was a 5 × 4 factorial randomized complete block design with three replications. Date of transplanting (5) and nutrient management (4) were the main effects, and there were 20 interactions. The size of unit plot was 4.0 m × 2.5 m. Poultry manure contains 1.20% N, 1.17% P, 0.80% K and 0.38% S. Healthy and vigorous seeds of aromatic *Boro* rice cv. BRRI dhan50 were collected from BRRI in Gazipur, Dhaka. Seeds were sown in the nursery bed on 15 November 2015, 30 November 2015, 15 December 2015, 30 December 2015 and 15 January 2016, respectively with proper care. The land was first opened with a power tiller and puddled thoroughly by repeated ploughing and cross ploughing with a country plough and subsequently leveled by laddering to have a good tilth. Weeds and stubble were cleared off from individual plots and finally plots were leveled properly. Both inorganic and organic fertilizers were applied in the plots according to the experimental treatments. Triple super phosphate (TSP), muriate of potash (MOP), gypsum, zinc sulphate ($ZnSO_4$) and poultry manure were applied at final land preparation as per treatment specification. Urea was top dressed in three equal splits at 15, 30 and 45 days after transplanting. Seedlings were transplanted on 15 December 2015, 30 December 2015, 15 January 2016, 30 January 2016 and 15 February 2016, respectively in the well puddled plot. Transplanting was done by using two seedlings $hill^{-1}$ with 25 cm × 15 cm spacing.

At maturity (i.e., 90% of the grain became golden yellow in color), one square meter area from each plot was selected from the central portion and was cut manually from the ground level to record grain and straw yields. Four hills were randomly selected from each plot (excluding boarder rows and

central 1 m^2) for recording data on crop characters and yield components. The harvested crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. The harvested crops were threshed manually. The grain was cleaned and dried to a moisture content of 14%. Straws were sun dried properly. Finally, grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}. Harvest index is the ratio of economic yield to biological yield expressed as a percentage and was calculated with the following formula:

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

Estimation of grain protein content in grains was done by following Micro–Kjeldahl Method (AOAC, 1984). Percentage of protein was obtained by multiplying nitrogen percentage by the factor of 5.95 (protein factor) as the following equation:

$$\text{Protein (\%)} = \text{Nitrogen (\%)} \times 5.95$$

Aroma Determination (Olfactory Method)

The aroma was determined at the Biochemistry and Molecular Biology Laboratory, Bangladesh Agricultural University, Mymensingh. Aroma of rice was detected by olfactory test (Nagaraju *et al.,* 1991). For performing this test, 5 g of kernel dehusked by hand from each sample was taken in airtight 20 ml vial and the kernels were treated with 5 ml of 0.1 N KOH solution to get just a submerged condition. The vials were kept for 45 minutes at normal room temperature. After treated, the odor released from the vial was detected by olfaction. This was done by a panel of five judges to estimate the intensity of aroma. Their scores were averaged for the final rating as described in Table 1.

Table 1 Scoring of rice aroma

Degree of aroma	Score	Type of quality
+	1	Good
++	2	Better
+++	3	Best

Statistical Analysis

The collected data were compiled and tabulated in the proper form and analyzed statistically. Analysis of variance (ANOVA) was done following the randomized complete block design (RCBD) with the help of computer package MSTAT (Power, 1985) and the mean differences among the treatments were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984) at 5% level of probability.

RESULTS AND DISCUSSION

Effect of Date of Transplanting (Main Effect)

The crop characters, yield contributing characters, yield and protein content of aromatic *Boro* rice were significantly influenced by date of transplanting (Table 2). The highest plant height (80.04 cm), number of total tillers $hill^{-1}$ (11.27), number of effective tillers $hill^{-1}$ (9.13), number of grains $panicle^{-1}$ (126.20), grain yield (5.15 t ha^{-1}), straw yield (7.60 t ha^{-1}) and grain protein content (8.30%) were recorded when the crop was transplanted on 15 December 2015 (Table 3). The crop transplanted on 30 December 2015 and 15 January 2016 were at par with that of 15 December 2015 in respect of plant height and number of grains $panicle^{-1}$. The lowest plant height (74.50 cm), number of total tillers $hill^{-1}$ (10.21), number of effective tillers $hill^{-1}$ (8.09), number of grains $panicle^{-1}$ (123.10), grain yield (4.79 t ha^{-1}), straw yield (6.43 t ha^{-1}), grain protein content (7.61%) and hightest harvest index (42.86%) were recorded when the

crop was transplanted on 15 February 2016 (Table 3). Effective tillers hill^{-1}, grains panicle, grain yield and grain protein content gradually decreased due to delayed transplanting. This was due to the fact that rice planted earlier had a longer period for their vegetative growth compared to those transplanted later. These results agree with the findings of BRRI (2003) who also observed more number of panicles and grains panicle^{-1} in early transplanting than in late transplanting. This might be due to the relatively higher temperature and the accumulation of lower photosynthetic products during delay transplanting. Variations in grain yield due to different dates of transplanting were also reported elsewhere (Rao *et al*., 2000; Mannan *et al*., 2012).

The highest number of sterile spikelets panicle^{-1} (20.30) was recorded on 15 February 2016 transplanting which was at par with the crop transplanted on 30 December 2015, 15 January 2016 and 30 January 2016 while the lowest number of sterile spikelets panicle^{-1} was recorded when the crop was transplanted on 15 December 2015 and ultimately resulted in the highest grain yield (Table 3). Delayed transplanting in *Boro* rice causes a lower number of grains panicle^{-1} due to higher grain sterility because of terminal heat stress occurring at the reproductive phase March to May resulting in lower grain yield.

Table 2 Summary of ANOVA (mean square values) of date of transplanting and nutrient management on crop characters, yield components, and yield quality of aromatic *Boro* rice (cv. BRRI dhan50)

Trait	Source of variation				
	Replication	Date of transplanting (A)	Nutrient management (B)	A × B	Error
	df = 2	df = 4	df = 3	df = 12	df = 38
Plant height (cm)	54.14	57.10**	86.25**	2.75^{ns}	12.88
Number of total tillers hill^{-1}	0.04	2.01**	8.07**	0.08*	0.04
Number of effective tillers hill^{-1}	0.01	1.67**	4.69**	0.29**	0.09
Number of non–effective tillers hill^{-1}	0.11	0.16**	0.50**	0.52**	0.04
Panicle length (cm)	0.80	0.52^{ns}	1.02*	0.05^{ns}	0.36
Number of grains panicle^{-1}	7.21	18.68*	487.06**	0.66^{ns}	7.12
Number of sterile spikelets panicle^{-1}	5.83	12.64*	46.68**	0.71^{ns}	4.59
1000–grain weight (g)	0.45	0.10^{ns}	1.39*	0.01^{ns}	0.47
Grain yield (t ha^{-1})	0.004	0.24**	12.50**	0.02*	0.01
Straw yield (t ha^{-1})	0.04	2.24**	16.86**	0.10*	0.05
Harvest index (%)	0.25	13.04**	34.75**	3.84*	1.72
Grain protein content (%)	0.33	0.10**	9.80**	0.06^{ns}	0.21
Aroma level	0.19	0.09^{ns}	10.26**	0.03^{ns}	0.10

Note: ** Significant at 1% level of probability, * significant at 5% level of probability, ns = not significant

Table 3 Effect of date of transplanting on crop characters, yield components, and yield quality of aromatic *Boro* rice (cv. BRRI dhan50)

Trait	Date of transplanting					LSD	Sig	CV (%)
	D_1	D_2	D_3	D_4	D_5			
Plant height (cm)	80.04^{a}	79.23^{a}	78.54^{a}	77.06^{ab}	74.50^{b}	2.18	**	4.61
Number of total tillers hill^{-1}	11.27^{a}	11.08^{b}	10.93^{b}	10.71^{c}	10.21^{d}	0.41	**	1.82
Number of effective tillers hill^{-1}	9.13^{a}	8.71^{b}	8.60^{b}	8.54^{b}	8.09^{c}	0.37	**	3.50
Number of non–effective tillers hill^{-1}	2.15^{c}	2.38^{a}	2.33^{ab}	2.17^{bc}	2.12^{c}	0.12	**	9.14
Panicle length (cm)	21.04	20.97	20.67	20.63	20.59	0.21	ns	2.87
Number of grains panicle^{-1}	126.20^{a}	125.30^{ab}	124.70^{ab}	123.70^{b}	123.10^{b}	1.25	*	2.14
Number of sterile spikelets panicle^{-1}	17.81^{b}	18.63^{ab}	19.18^{ab}	20.05^{a}	20.30^{a}	1.03	*	11.17
1000–grain weight (g)	19.30	19.22	19.18	19.12	19.06	0.09	ns	3.57
Grain yield (t ha^{-1})	5.15^{a}	5.04^{b}	4.92^{c}	4.86^{cd}	4.79^{d}	0.14	**	2.13
Straw yield (t ha^{-1})	7.60^{a}	7.28^{b}	7.13^{bc}	7.00^{c}	6.43^{d}	0.43	**	3.17
Harvest index (%)	40.18^{b}	40.73^{b}	40.64^{b}	40.83^{b}	42.86^{a}	1.04	**	3.20
Grain protein content (%)	8.30^{a}	8.14^{a}	7.94^{ab}	7.71^{b}	7.61^{b}	0.29	**	5.71
Aroma level	2.08	2.08	1.92	1.92	2.00	0.09	ns	16.22

Note: D1 = 15 December 2015, D2 = 30 December 2015, D3 = 15 January 2016, D4 = 30 January 2016 D5 = 15 February 2016, LSD = least significant difference, Sig = level of significance, CV = coefficient of variation, $^{a, b, c, d}$ different letters in the same row indicated significant differences of the Duncan's Multiple Range Test, ** significant at 1% level of probability, * significant at 5% level of probability, ns = not significant

Effect of Nutrient Management (Main Effect)

The crop characters, yield components, yield, grain protein content and aroma level of aromatic *Boro* rice were significantly influenced by nutrient management (Table 2). The highest plant height (80.58 cm), number of total tillers hill^{-1} (11.65), number of effective tillers hill^{-1} (9.18), number of non–effective tillers hill^{-1} (2.47), panicle length (21.07 cm), number of grains panicle^{-1} (130.50), 1000–grain weight (19.41 g), grain yield (5.64 t ha^{-1}) and straw yield (8.24 t ha^{-1}) were recorded when the crop was fertilized with 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure and among the parameters-plant height, panicle, 1000–grain weight and grain yield were at length par when fertilized with 100% recommended dose of inorganic fertillizers. The hidhest harvest index (42.50%) was obtained in 100% recommended dose of inorganic fertillizers. The corresponding lowest values of all characters were recorded when fertilized with poultry manure 5 t ha^{-1}. The highest grain protein content (8.81%) was obtained in 25% less than recommended dose of inorganic fertilizer + 2.5 t ha^{-1} poultry manure followed by recommended dose of inorganic fertilizer (8.36%) and the lowest value was obtained in poultry manure at 5 t ha^{-1} (Table 4). Integration of poultry manure and with inorganic fertilizer increased protein content in grains were also reported elsewhere (Sarkar *et al.,* 2014; Biswas *et al*., 2016).

The highest aroma (3.00) was found in 25% less than recommended dose of inorganic

fertilizer +2.5 t ha^{-1} poultry manure. The lowest (1.00) aroma was observed when fertilized with sole poultry manure at 5 t ha^{-1} (Table 4). These findings are in conformity with that of Sarkar *et al.* (2014). Poultry manure as an organic matter improved soil aeration, water holding capacity and microbial activity which ultimately improve the nutrient uptake of the crop resulting in higher yield.

Table 4 Effect of nutrient management on crop characters, yield components, and yield quality of aromatic *Boro* rice (cv. BRRI dhan50)

Trait	Nutrient management (Fertilizer)				LSD	Sig	CV (%)
	F_1	F_2	F_3	F_4			
Plant height (cm)	78.55^{ab}	74.82^{c}	80.58^{a}	77.55^{b}	2.40	**	4.61
Number of total tillers hill^{-1}	11.17^{b}	9.95^{d}	11.65^{a}	10.60^{c}	0.73	**	1.82
Number of effective tillers hill^{-1}	8.90^{b}	7.90^{d}	9.18^{a}	8.47^{c}	0.56	**	3.50
Number of non-effective tillers hill^{-1}	2.27^{b}	2.05^{c}	2.47^{a}	2.13^{bc}	0.18	**	9.14
Panicle length (cm)	20.73^{ab}	20.45^{b}	21.07^{a}	20.87^{ab}	0.26	*	2.87
Number of grains panicle^{-1}	121.50^{c}	118.20^{d}	130.50^{a}	128.10^{b}	5.70	**	2.14
Number of sterile spikelets panicle^{-1}	19.73^{b}	21.34^{a}	17.19^{c}	18.53^{bc}	1.76	**	11.17
1000–grain weight (g)	19.20^{ab}	18.74^{b}	19.41^{a}	19.35^{a}	0.30	*	3.57
Grain yield (t ha^{-1})	5.59^{a}	3.68^{c}	5.64^{a}	4.89^{b}	0.91	**	2.13
Straw yield (t ha^{-1})	7.54^{b}	5.76^{d}	8.24^{a}	6.81^{c}	1.06	**	3.17
Harvest index (%)	42.59^{a}	39.11^{c}	40.64^{b}	41.86^{a}	1.52	**	3.20
Grain protein content (%)	8.36^{b}	6.98^{d}	8.81^{a}	7.61^{c}	0.81	**	5.71
Aroma level	1.80^{b}	1.00^{c}	3.00^{a}	2.20^{b}	0.83	**	16.22

Note: F_1 = recommended dose of inorganic fertilizer (N, P, K, S and Zn at the rate of 115, 25, 60, 18, 3.5 kg ha^{-1}, respectively), F_2 = poultry manure 5 t ha^{-1}, F_3 = 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure, F_4 = 50% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure, LSD = least significant difference, Sig = level of significance, CV = coefficient of variation, $^{a, b, c, d}$ different letters in the same row indicated significant differences of the Duncan's Multiple Range Test, ** significant at 1% level of probability, * significant at 5% level of probability

Effect of Interaction between Date of Transplanting and Nutrient Management (Combined Effect)

Number of total tillers hill^{-1}, number of effective tillers hill^{-1}, number of non-effective tillers hill^{-1}, grain yield, straw yield and harvest index were significantly affected by the interaction between date of transplanting and nutrient management (Table 2). The highest number of total tillers hill^{-1} (12.00), number of effective tillers hill^{-1} (10.00), grain yield (5.90 t ha^{-1}) and straw yield (8.80 t ha^{-1}) were obtained when the crop was transplanted on 15 December 2015 and fertilized with 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure (Table 5 and Table 6). Due to transplanting on 15 December 2015 plants got longer time for its proper vegetative growth

and integration of poultry manure improved soil quality (lower C : N ratio, facilitate aeration and water holding capacity) where more nutrients were made readily available and easily absorbable by receiving plants leading to faster growth and development thus ultimately increased grain yield. Application of poultry manure increased grain yield of rice was reported by Mohandas *et al*. (2008) and Hidaytullah (2015).

Transplanting on 15 December 2015 and fertilization with recommended dose of inorganic fertilizer, 30 December 2015 transplanting and fertilized with 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure and 30 December 2015 transplanting and fertilization with recommended dose of inorganic fertilizer were as good as transplanting on 15 December 2015 and fertilization with 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure in respect of grain yield. The lowest grain yield (3.60 t ha^{-1}) was recorded on 15 January 2016 transplanting and fertilization with poultry manure 5 t ha^{-1} while the highest harvest index (43.47%) was recorded on 15 February 2016 transplanting and fertilized with 5 t ha^{-1} poultry manure. (Table 6). The grain protein content was not significantly influenced by the interaction between date of transplanting and nutrient management. However, numerically the highest grain protein content (9.25%) was obtained on 30 December 2015 transplanting and fertilization with 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure followed by transplanted on 15 December 2015 fertilization with 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure and the lowest one was recorded on 15 February 2016 transplanting with poultry manure 5 t ha^{-1} (Table 6). Poultry manure alone could not supply enough nutrients to the plant within a very short period of time as was noticed its sole application in the crop but when it was applied in combination with a suitable amount of inorganic fertilizer resulted in higher yield at optimum transplanting date.

Table 5 Effect of interaction between date of transplanting and nutrient management on crop characters and yield components of aromatic *Boro* rice (cv. BRRI dhan50)

Factor	Plant height (cm)	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}	Number of non–effective tillers hill^{-1}	Panicle length (cm)	Number of grains panicle^{-1}	Number of sterile spikelets panicle^{-1}
$D_1 \times F_1$	80.00	11.58^{bcd}	9.25^{b}	2.33^{cd}	20.89	122.8	18.02
$D_1 \times F_2$	77.50	10.58^{gh}	8.58^{cde}	1.99^{def}	20.56	119.3	19.46
$D_1 \times F_3$	83.00	12.00^{a}	10.00^{a}	2.00^{def}	21.56	133.2	16.02
$D_1 \times F_4$	79.67	10.92^{fg}	8.66^{bcd}	2.25^{cd}	21.16	129.6	17.72
$D_2 \times F_1$	79.08	11.50^{cd}	9.00^{bc}	2.50^{bc}	20.89	122.3	19.01
$D_2 \times F_2$	77.42	10.08^{i}	8.25^{def}	1.83^{ef}	20.50	118.7	20.50
$D_2 \times F_3$	82.50	11.92^{ab}	9.00^{bc}	2.92^{a}	21.41	131.3	17.14
$D_2 \times F_4$	77.92	10.83^{fg}	8.58^{cde}	2.25^{cd}	21.07	128.9	17.88
$D_3 \times F_1$	79.00	11.33^{de}	8.83^{bc}	2.49^{bc}	20.66	121.7	19.14
$D_3 \times F_2$	76.08	9.75^{ij}	8.08^{ef}	1.66^{f}	20.43	118.6	21.82
$D_3 \times F_3$	81.17	11.83^{abc}	9.00^{bc}	2.83^{ab}	20.82	130.4	17.31
$D_3 \times F_4$	77.92	10.83^{fg}	8.50^{cde}	2.33^{cd}	20.75	128.0	18.47

Table 5 Continue

Factor	Plant height (cm)	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}	Number of non–effective tillers hill^{-1}	Panicle length (cm)	Number of grains panicle^{-1}	Number of sterile spikelets panicle^{-1}
$D_4 \times F_1$	78.83	11.00^{ef}	8.75^{bcd}	2.25^{cd}	20.62	120.5	21.07
$D_4 \times F_2$	72.33	9.75^{ij}	7.91^{f}	1.83^{ef}	20.39	117.8	22.37
$D_4 \times F_3$	79.50	11.50^{cd}	9.00^{bc}	2.50^{bc}	20.81	129.3	17.47
$D_4 \times F_4$	77.58	10.58^{gh}	8.50^{cde}	2.08^{de}	20.71	127.2	19.31
$D_5 \times F_1$	75.83	10.42^{h}	8.67^{bcd}	1.74^{ef}	20.60	120.4	21.41
$D_5 \times F_2$	70.75	9.58^{j}	6.67^{g}	2.91^{a}	20.36	116.7	22.54
$D_5 \times F_3$	76.75	11.00^{f}	8.92^{bc}	2.08^{de}	20.74	128.4	18.01
$D_5 \times F_4$	74.66	9.83^{ij}	8.08^{ef}	1.75^{ef}	20.65	126.8	19.25
LSD	3.02	0.76	0.65	0.38	0.32	5.20	1.87
Sig	ns	*	**	**	ns	ns	ns
CV (%)	4.61	1.82	3.50	9.14	2.87	2.14	11.17

Note: D1 = 15 December 2015, D2 = 30 December 2015, D3 = 15 January 2016, D4 = 30 January 2016 D5 = 15 February 2016, F_1 = recommended dose of inorganic fertilizer (N, P, K, S and Zn at the rate of 115, 25, 60, 18, 3.5 kg ha^{-1}, respectively), F_2 = poultry manure 5 t ha^{-1}, F_3 = 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure, F_4 = 50% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure, LSD = least significant difference, Sig = level of significance, CV = coefficient of variation, $^{a, b, c, d, e, f, i, j}$ different letters in the same column indicated significant differences of the Duncan's Multiple Range Test, ** significant at 1% level of probability, * significant at 5% level of probability, ns = not significant

Table 6 Effect of interaction between date of transplanting and nutrient management on yield components, and yield quality of aromatic *Boro* rice (cv. BRRI dhan50)

Factor	1000–grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Grain protein content (%)	Aroma level
$D_1 \times F_1$	19.39	5.87^{a}	7.98^{bc}	42.40^{abcd}	8.86	2.00
$D_1 \times F_2$	18.88	3.76^{j}	6.22^{f}	37.70^{g}	7.30	1.00
$D_1 \times F_3$	19.50	5.90^{a}	8.80^{a}	40.16^{def}	9.10	3.00
$D_1 \times F_4$	19.43	5.03^{g}	7.41^{d}	40.44^{de}	7.92	2.30
$D_2 \times F_1$	19.28	5.72^{abc}	7.71^{bcd}	42.58^{abcd}	8.50	2.00
$D_2 \times F_2$	18.81	3.69^{j}	6.03^{f}	37.99^{fg}	7.00	1.00

Table 6 Continue

Factor	1000–grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Grain protein content (%)	Aroma level
$D_2 \times F_3$	19.42	5.76^{ab}	8.53^{a}	40.33^{def}	9.25	3.00
$D_2 \times F_4$	19.37	4.96^{gh}	6.85^{e}	42.01^{abcd}	7.81	2.30
$D_3 \times F_1$	19.15	5.56^{cde}	7.65^{cd}	42.13^{abcd}	8.39	1.67
$D_3 \times F_2$	18.80	3.60^{j}	5.94^{f}	37.74^{g}	6.98	1.00
$D_3 \times F_3$	19.41	5.62^{bcd}	8.10^{b}	40.99^{bcd}	8.90	3.00
$D_3 \times F_4$	19.35	4.87^{ghi}	6.81^{e}	41.71^{abcd}	7.50	2.00
$D_4 \times F_1$	19.13	5.47^{def}	7.43^{d}	42.40^{abcd}	8.05	1.67
$D_4 \times F_2$	18.65	3.67^{j}	5.90^{f}	38.38^{efg}	6.87	1.00
$D_4 \times F_3$	19.38	5.49^{def}	7.98^{bc}	40.74^{cde}	8.48	3.00
$D_4 \times F_4$	19.31	4.81^{hi}	6.69^{e}	41.83^{abcd}	7.42	2.00
$D_5 \times F_1$	19.05	5.32^{f}	6.93^{e}	43.43^{ab}	8.00	1.67
$D_5 \times F_2$	18.55	3.66^{j}	4.72^{g}	43.74^{a}	6.75	1.00
$D_5 \times F_3$	19.34	5.40^{ef}	7.79^{bcd}	40.97^{bcd}	8.30	3.00
$D_5 \times F_4$	19.31	4.75^{i}	6.27^{f}	43.29^{abc}	7.38	2.00
LSD	0.29	0.82	1.03	1.89	0.77	0.74
Sig	ns	*	*	*	ns	ns
CV (%)	3.57	2.13	3.17	3.20	5.71	16.22

Note: D1 = 15 December 2015, D2 = 30 December 2015, D3 = 15 January 2016, D4 = 30 January 2016 D5 = 15 February 2016, F_1 = recommended dose of inorganic fertilizer (N, P, K, S and Zn at the rate of 115, 25, 60, 18, 3.5 kg ha^{-1}, respectively), F_2 = poultry manure 5 t ha^{-1}, F_3 = 25% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure, F_4 = 50% less than recommended dose of inorganic fertilizer +2.5 t ha^{-1} poultry manure, LSD = least significant difference, Sig = level of significance, CV = coefficient of variation, $^{a, b, c, d, e, f, i, j}$ different letters in the same column indicated significant differences of the Duncan's Multiple Range Test, ** significant at 1% level of probability, * significant at 5% level of probability, ns = not significant

CONCLUSION

Present findings confirm the advantages of early transplanting of aromatic *Boro* rice and the combined application of inorganic fertilizers with poultry manure compared to their sole application. Results revealed that transplanting on 15 December and fertilization with 25% less than recommended dose of inorganic fertilizers +2.5 t ha^{-1} poultry manure appears to be the best practice in aromatic *Boro* rice (cv. BRRI dhan50) cultivation in terms of grain yield and grain protein content under Old Brahmaputra Floodplain Soils of Bangladesh.

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REFERENCES

Akram, M., A.A. Cheema, M.A. Awan and M. Ahmad. 1985. Effect of planting date and fertilizer level on grain yield and protein content of rice. Pak. J. Agric Res. 6(3): 165–167.

AOAC (Association of Official Analytical Chemists). 1984. Official Methods of Analysis. Association of Official Agricultural Chemists, Washington, D.C., USA.

Biswas, T., S.K. Paul, M.A.R. Sarkar and S.K. Sarkar. 2016. Integrated use of poultry manure with prilled urea and urea super granules for improving yield and protein content of aromatic rice (cv. BRRI dhan50). Progress. Agric. 27(2): 86–93.

BRRI (Bangladesh Rice Research Institute). 2003. Annual Internal Review Held on 19 October–23 October. Genetic Resources and Seed Division, Bangladesh Rice Research Institute, Gazipur.

Ferreras, L., E. Gomez, S. Toresani, I. Firpo and R. Rotondo. 2006. Effect of organic amendments on some physical, chemical and biological properties in a horticultural soil. Bioresour. Technol. 97(4): 635–640.

Gomez, K.A. and A.A. Gomez. 1984. Statistical Procedure for Agricultural Research. John Wiley & Sons, Inc., New Jersey, USA.

Gomez, K.A. and S.K. De Datta. 1975. Influence of environment on protein content of rice. Agron. J. 67: 565–568.

Hidaytullah. 2015. Organic and Inorganic N–Fertilizer Management for Rice under Rice–Wheat Cropping System. Ph.D. Thesis, The University of Agriculture Peshawar, Pakistan.

Islam, M.S., M.A.R. Sarkar, M.J. Alam, M.A. Kashem, M.Y. Rafi and M.A. Latif. 2014. Effect of date of transplanting on yield and yield attributing characters of aromatic fine rice in rainfed condition. Res. Crop. 15(2): 305–312.

Mannan, M.K., M.S.U. Bhuiya, M.I.M. Akhand and M.M. Rana. 2012. Influence of date of planting on the growth and yield of locally popular traditional aromatic rice varieties in boro season. J. Sci. Foundation 10(1): 20–28.

Mohandas, S., V. Paramasivam and N. Sakthivel. 2008. Phosphorus and zinc enriched organics for enhancing the yield of transplanted rice in new Cauvery Delta, Tamil Nadu. J. Ecobiol. 23: 73–76.

Mukesh, I. Singh, R.K. Pannu, D. Prasad and A. Ram. 2013. Effect of different transplanting dates on yield and quality of basmati rice (*Oryza sativa*) varieties. Indian J. Agron. 58(2): 256–258.

Nagaraju, M., K.K. Mohanty, D. Chowdhury and C. Gangadharan. 1991. A simple technique to detect scent in rice. Oryza 28: 109–110.

Pal, S., S.K. Paul, M.A.R. Sarkar and D.R. Gupta. 2016. Response on yield and protein content of fine aromatic rice varieties to integrated use of cowdung and inorganic fertilizers. J. Crop Weed. 12(1): 1–6.

Power, P. 1985. User's to MSTAT (version 4.0): A Software Program for the Design, Management, and Analysis of Agronomic Research Experiment. Michigan State University, USA.

Rao, C.B.B., S. Mohammad and A.U. Rao. 2000. Influence of varietal option and time of planting on grain yield and quality of scented rice. Gujarat Agric. Univ. Res. J. 26: 23–26.

Ray, S., M.A.R. Sarkar, S.K. Paul, A.K.M.M. Islam and S. Yeasmin. 2015. Variation of growth, yield and protein content of transplant Aman rice by three agronomic practices. Agricultural and Biological Sciences Journal. 1(4): 167–176.

Sarkar, S.K., M.A.R. Sarkar, N. Islam and S.K. Paul. 2014. Yield and quality of aromatic fine rice as affected by variety and nutrient management. J. Bangladesh Agril. Univ. 12(2): 279–284.

UNDP (United Nations Development Programme) and FAO (Food and Agriculture Organization of the United Nations). 1988. Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2: Agroecological Regions of Bangladesh. Bangladesh Agricultural Research Council, Dhaka.