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Screening Rice Germplasm against Sheath Blight Disease of Rice and its Integrated Management in Bangladesh

S Parveen[1*], M A Ali[2] and M A Ali[3]

ABSTRACT

Fifty-seven rice germplasm collected from BRRI Genebank were screened against sheath blight (ShB) by artificial inoculation in field and laboratory conditions in T. Aman 2012. Significant differences on relation to lesion height (RLH) among the germplasm were observed, where the highest (83%) was recorded in susceptible check, BR11 and the lowest (8.33%) was in Orgoja. Severity score of ShB was recorded maximum (9) in Dudhsail, Basi, Chaula mari, Holdemota, Calendamota, Semmua, Kotijira, Halisail, Horakani, Kalisura, Ashfuli, Huglapata and BR11 as highly susceptible to ShB, whereas it was minimum (1) in Orgoja. Gopal ghosh was observed as moderately tolerant with 27.33% RLH and severity score 3, while Kala binni, Khazur chari, Binni, Kalagora, Patjait and Dorkumur found moderately tolerant with severity score 5. In detached sheath inoculation method in test tube, most of the germplasms found highly susceptible, except Orgoja as resistant and Gopal ghosh as moderately tolerant. However, Orgoja showed resistance in both field inoculation and detached sheath inoculation methods. But, Dorkumur was found moderately tolerant in field and highly susceptible in detached sheath inoculation in laboratory. The experiment of Integrated Disease Management (IDM) packages was conducted in the farmer's field with BR11 at Fulpur, Mymensingh during T. Aman 2013. The IDM practices of rice ShB resulted profound effect. Relative lesion height, percent disease index, tiller infection and hill infection were maximum (68%, 69%, 86% and 79% respectively) in T_6 (control) and minimum in T_1 [FDR (removal of floating debris) + 30 July transplanting + Potash (K) fertilizer (202 g decimal^{-1}) + Top dressing of urea (247 kg ha^{-1}) in four equal splits at 15 days interval + single spray of fungicides of Azoxystrobin 10% (0.17 kg ha^{-1}) + Tebuconazole 90% (500 ml ha^{-1})]. Moreover, the highest number of panicles per m^2, filled grains per panicle and grains yield were recorded in T_1 (160, 150 and 6.25 t ha^{-1} respectively) and the minimum in T_6 (227, 120 and 3.6 t ha^{-1} respectively). Therefore, the best IDM package was T_1 for its effective control of ShB disease as well as yield maximization of rice. Finally, Orgoja could be used in resistance breeding for varietal improvement and the IDM package of T_1 need to be recommended to prescribe in the farmer's field after simulation in different AEZs and seasons with different varieties of Bangladesh.

Key words: Germplasm, resistance, integrated management, sheath blight, rice

INTRODUCTION

Bangladesh agriculture involves food production for 163.65 million people (Salam *et al.*, 2014), where rice is the principal food. This increasing population requires increasing crop yields for stable supply of grain to achieve food security of the country. Consequently, the national average production needs to be increased from 3 to 5 t ha^{-1} in next 20 years (Mahbub *et al.*, 2001). In Bangladesh, rice production area is 11.01 million hectares of land during 2016-17 (BBS, 2018). However, 36.27 million metric tons of rice is produced in the country during 2017-18 (AIS, 2019). Sheath blight (ShB) of rice was first reported in Japan by Miyakie in 1910. It is caused by *Rhizoctonia solani* Kuhn. It is considered as the most damaging major epidemic disease of rice (Li *et al.*, 2012). ShB is an important disease of rice, especially in intensive rice production systems. The average incidence of ShB in Bangladesh is about 20.3% (Ali *et al.*, 2003). The yield loss caused by ShB in Bangladesh ranged from 14 to 31% under farmer's field (Shahjahan *et al.*, 1986). The presence of one or many factors

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may enhance the severity of ShB beyond economic threshold levels, thereby incurring low to high yield losses.

Incidence and development of ShB of rice depends on climate, host and soil factor (Damicone *et al.*, 1993). Short duration and semi-dwarf cultivars are more susceptible to ShB (Groth and Lee, 2002). During rice ShB epidemics, severe lodging may occur (Wu *et al.*, 2012). Differences in yield loss between very susceptible and moderately resistant cultivars are substantial. On infection by *Rhizoctonia solani,* semi-dwarf varieties show more than twice the reduction in yield and milling quality.

Breeding for resistance against ShB has not been successful due to lack of sources of resistant genes (Rao, 1995; Hashiba and Kobayashi, 1996). Resistance source against ShB disease of rice is not available in Bangladesh and anywhere (Jalal Uddin *et al.*, 2000). Consequently, none of the high yielding varieties is resistant to ShB disease neither in Bangladesh nor elsewhere in the world. Fortunately, rice land races have proven to be highly adaptive to diverse environmental conditions and are believed to harbour a number of valuable genetic resources for crop improvement (Karmakar *et al.*, 2012; Roychowdhury *et al.*, 2013; Ganie *et al.*, 2014). Some of the landraces such as Buhjan, Banshpata, Bhasamanik, Nagra Sail, Raghu Sail are tolerant to rice ShB (Dey, 2014). Therefore, local or land races of rice need to be exploited for getting resistant or moderately resistant or even better tolerant sources for ShB disease.

The control of ShB in the field so far is mainly relied on the use of fungicides, which is not sustainable for its residual effect along with the potential risk of resistant to fungicides overtime. Disease management programme against ShB can concentrate different approaches such as incorporating cultural practices, exploitation of host resistance, biological control with *Trichoderma harzianum* and *Trichoderma viride* and chemical control. Ashrafuzzaman *et al*. (2005) also reported that emphasis should be given on different management options to control ShB disease of rice. For clean cultivation, burning the crop residues, destroy grasses and other hosts from the field, collecting and burying floating debris after final land preparation may reduce infection foci. Instead of applying excess dose of nitrogen, split application of K fertilizer with last top dress of urea can reduce its infestation. Application of 40 kg MP/ha as top dress in two equal splits and transplanting with 20 cm × 20 cm spacing have affect on ShB (Hossain and Mia, 2001). Large amount of N and phosphate (P) is favourable for ShB disease (Dasgupta, 1992) and high potash (K) or PK is useful for infection (CRRI, 1977). Therefore, the present research programme was planned and designed to develop management technologies of the disease with the aim of recommending suitable control strategies in Bangladesh. The present study was under taken to screen germplasm for their reaction to ShB and to develop an integrated management practice for controlling ShB of rice in Bangladesh.

MATERIALS AND METHODS

Screening of rice germplasm against ShB of rice

Rice germplasm. A total of 57 rice germplasm collected from BRRI Genebank were screened against ShB disease of rice in the field through hill inoculation method and BR11 was used as susceptible check (Table 1).

Table 1. Primary information of the germplasms used for screening resistance source against sheath blight.

Acc. no.*	Variety	Acc. no.	Variety	Acc. no.	Variety
4111	Gopal ghosh	4794	Kalahati	5221	Kalisura
4112	Chata bazail	4795	Khajur chhori	5222	Akra
4113	Ram dash	4849	Rayeda	5223	Ushi har
4114	Paizra	5121	Jamni	5250	Ashfuli
4118	Kala binni	5122	Chaula maghi	5286	Ranisalut
4149	Beto	5190	Bushi hara (mota)	5289	Buripagli
4155	Chini kani	5192	Lohamugra	5298	Harisankar
4156	Minki	5193	Chaula mari	5300	Birinde
4162	Kasrail	5194	Kalagora	5310	Orgoja
4163	Khazur chari	5195	Patjait	5316	Nonamurchi
4239	Binni	5196	Holdemota	5319	Gandhakusturi
4267	Birpala	5197	Kanchachikon	5327	Huglapata
4271	Rayda	5198	Dholeshwar mota	5329	Gota
4272	Dhaki rayda	5199	Calendamota	5330	Dorkumur
4768	Kaijhuri	5212	Semmua	5337	Changi
4773	Dudhsail	5213	Kotijira	5345	Rasasail
4777	Kashra	5217	Ashkor	5347	Sackhorkhana
4778	Katarangi	5218	Baskor	--	BR11
4792	Basi	5219	Halisail		
4793	Sada pankaich	5220	Horakani		

* BRRI Genebank accession number.

Field experiment. The experiment was conducted at the experiment field of Bangladesh Rice Research Institute (BRRI), Gazipur during T. Aman 2012. A levee was made surrounding plots to maintain standing water up to 5.0 cm inside. Land was prepared 15 days before transplanting/seedling. Ploughing and cross ploughing followed by laddering was done by power tiller. Weeds were cleaned manually. The seedlings of the tested germplasms were raised in plastic tray in the Plant Pathology net house. Thirty-day-old 2-3 seedlings per hill were transplanted with a spacing of 20 cm × 15 cm. Fertilizers were applied @ 405: 150: 202: 135: 10 g decimal^{-1} of urea, TSP, MOP, gypsum and zinc sulphate. All fertilizers were applied in basal, except urea (Anonymous, 2010). For agronomic, weed management, irrigation and drainage and insect management current standard recommendations were followed (Anonymous, 2007).

Preparation of inoculum. One hundred PDA plates in glass petridishes were prepared following the standard procedure. The fungus (*Rhizoctonia solani)* was grown in the petridishes containing PDA medium and incubated for seven days at room temperature (25 to 30°C) for growth and development of the pathogen.

Inoculation of pathogen. Inoculations were done at maximum tillering stage (Bhaktavatsalam *et al.*, 1978). Two methods of inoculation were employed for inoculation of germplasms by *Rhizoctonia solani*. After seven days of inoculation lesion length and leaf sheath length were measured and calculated. The methods were as follows:

a. Hill inoculation-Total hill were inoculated with *Rhizoctonia solani* Kuhn culture (7 days) grown on PDA medium. Prior to inoculation, eight hills were tagged randomly in the central area of each plot in the field for inoculation. Inoculation was done by inserting a piece of culture medium (cutting the culture medium into eight pieces) at the middle of each hill in the afternoon, colonized by the ShB pathogen in a tagged rice hill and maintained standing water onward of the crop growth to maintained high moisture below canopy level for disease development (Sharma and Teng, 1990).

b. Detached sheath inoculation-Detached sheath was inoculated in moist test tube (Fig. 1). In detached sheath inoculation method, one tiller from each entry was taken *i.e.* three tillers for three replications. Tillers were cut in such a way that leaf sheath did not separate from stem or remain in contact with stem and uniform in size. Water soaked cotton was placed at the bottom of the test tube and then placed 6-9 mm mycelial block (growing pathogen) inside the sheath. The test tube was then plugged with soaked cotton.

Data recording. The disease severity was recorded from the data collected from 25 hills in each replication of each treatment. Severity was calculated by relative lesion height (RLH) (McKinney, 1923). Data were recorded for each treatment following standard evaluation system (SES) for rice in 0-9 scale (Anonymous, 1996). Data of the lesion height, plant height, 1000 grain weight and grain yield (g hill^{-1}) were also recorded. In detached sheath inoculation method, ShB severity was measured by RLH using the following formula-

$$RLH = \frac{\text{Lesion height (cm)}}{\text{Leaf sheath height (cm)}} \times 100$$

Integrated management of ShB of rice

Field experiment. The experiment was conducted in the farmer's field with BR11 at Fulpur, Mymensingh during T. Aman 2013. Plant to plant spacing was 15 cm and row to row distance was 16 cm. Randomized RCBD was used with four replications. Plot size was 2.5 m × 4 m. Plot to plot distance was 0.5 m and block to block distance was 1 m. The best options obtained from the results of different experiments (Parveen, 2016) were included into integrated disease management (IDM) packages and were simulated in the field. The treatments used in this study were shown below:

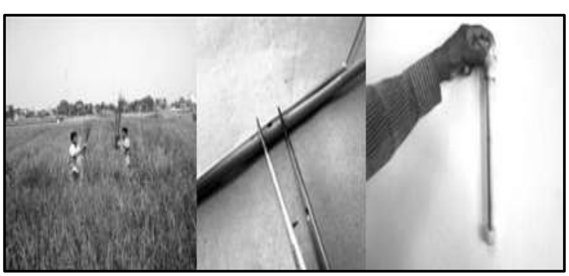

Fig. 1. Detached sheath inoculation method of screening against ShB of rice.

T_1=FDR (removal of floating debris) + 30 July planting + Potash (K) fertilizer (202 g decimal^{-1}) + Top dressing of urea (247 kg ha^{-1}) in four equal splits at 15 days interval + single spray of fungicide [Azoxystrobin 10% (0.17 kg ha^{-1}) + Tebuconazole 90% (500 ml ha^{-1})]. T_2= 30 July planting + K-dose + top dressing of urea in four equal splits at 15 days interval + single spray of fungicide. T_3= K-dose + top dressing of urea in four equal splits at 15 days interval + single spray of fungicide. T_4= Top dressing of urea in four equal splits at 15 days interval + single spray of fungicide. T_5= Single spray of fungicide. T_6= Control.

Inoculation of pathogen. Same as hill inoculation method.

Data collection. Twenty-five hills were selected at random from each experimental unit. Number of infected tillers and hills were counted. Incidence was recorded by tiller infection and expressed in percentage, while severity by relative lesion height (RLH) and percent disease index (PDI) (McKinney, 1923). Data were recorded for each treatment following standard evaluation system (SES) for rice in 0-9 scale (Anonymous, 1996). Data on total tiller, infected tiller, plant height, panicle per m^2, filled grain, unfilled grain, 1000 grain weight (TGW) and grain yield were also recorded. PDI was measured by using the following formula-

$$PDI = \frac{\text{Total rating}}{\text{No. of observation} \times \text{Maximum grade}} \times 100$$

Statistical analysis. The data were subjected to statistical analysis and ANOVA (analysis of variance) were constructed following RCBD by SPSS 2.05 programme for both the experiments. The treatment means were compared by LSD test at probability level P=0.05.

RESULTS AND DISCUSSION

Assessment of germplasm against ShB of rice

Table 2 shows that there was a variation among the germplasms on ShB disease development and yield through hill inoculation in the field. Significant differences on RLH among the germplasms were observed. The highest RLH was recorded in BR11 (83%) and the lowest was in Orgoja (8.33%). The maximum (9) severity (SES) score of ShB was recorded in Dudhsail, Basi, Chaula mari, Holdemota, Calendamota, Semmua, Kotijira, Halisail, Horakani, Kalisura, Ashfuli, Huglapata and BR11, which were highly susceptible (HS) to ShB disease, whereas the minimum severity score (1) was observed in Orgoja. Gopal ghosh was observed as moderately tolerant to ShB disease with 27.33% RLH and severity score 3. Moreover, Kala binni, Khazur chari, Binni, Kalagora, Patjait and Dorkumur found moderately tolerant to ShB with severity score 5. On the other hand, the highest yield was found in Beto (18.23 g hill^{-1}), Rayda (18.15), Ushi har (18.23) and Buripagli (18.15) and the lowest in Kashra, Calendamota, Orgoja and Sackhorkhana (4.85 g hill^{-1}) germplasms (Table 3).

Table 2. Reaction of screened germplasm against ShB due to artificial inoculation of *Rhizoctonia solani* through hill inoculation method in the field.

Acc. no.	Variety	Growth duration	Plant height (cm)	RLH (%)	SES score	Reaction
4111	Gopal ghosh	150	131	27.33	3	MT
4112	Chata bazail	151	140	47.66	7	HS
4113	Ram dash	152	144	54.00	7	HS
4114	Paizra	149	127	63.00	7	HS
4118	Kala binni	151	129	38.00	5	MT
4149	Beto	155	154	53.00	7	HS
4155	Chini kani	147	141	61.66	7	HS
4156	Minki	156	141	61.33	7	HS
4162	Kasrail	154	141	53.66	7	HS
4163	Khazur chari	148	141	41.33	5	MT
4239	Binni	147	137	43.66	5	MT
4267	Birpala	141	136	54.33	7	HS
4271	Rayda	149	136	50.33	7	HS
4272	Dhaki rayda	146	150	60.00	7	HS
4768	Kaijhuri	142	119	56.33	7	HS
4773	Dudhsail	154	149	69.00	9	HS
4777	Kashra	145	147	51.66	7	HS
4778	Katarangi	145	151	64.66	7	HS
4792	Basi	140	115	75.33	9	HS
4793	Sada pankaich	138	149	53.66	7	HS
4794	Kalahati	143	149	62.33	7	HS
4795	Khajur chhori	142	150	56.66	7	HS
4849	Rayeda	145	152	56.33	7	HS
5121	Jamni	147	150	64.66	7	HS
5122	Chaula maghi	149	144	63.33	7	HS
5190	Bushi hara (mota)	150	153	57.00	7	HS
5192	Lohamugra	149	150	55.33	7	HS

Table 2. Continued.

Acc. no.	Variety	Growth duration	Plant height (cm)	RLH (%)	SES score	Reaction
5193	Chaula mari	145	151	72.66	9	HS
5194	Kalagora	149	141	42.33	5	MT
5195	Patjait	149	152	45.00	5	MT
5196	Holdemota	150	146	68.66	9	HS
5197	Kanchachikon	153	156	64.66	7	HS
5198	Dholeshwar mota	154	165	60.33	7	HS
5199	Calendamota	155	161	66.33	9	HS
5212	Semmua	152	142	69.33	9	HS
5213	Kotijira	150	134	70.00	9	HS
5217	Ashkor	149	146	55.33	7	HS
5218	Baskor	150	158	49.33	7	HS
5219	Halisail	148	149	66.00	9	HS
5220	Horakani	148	166	67.33	9	HS
5221	Kalisura	149	144	74.33	9	HS
5222	Akra	148	174	54.00	7	HS
5223	Ushi har	152	144	52.66	7	HS
5250	Ashfuli	161	98	66.66	9	HS
5286	Ranisalut	165	147	59.00	7	HS
5289	Buripagli	163	165	58.33	7	HS
5298	Harisankar	153	164	51.33	7	HS
5300	Birinde	157	150	64.66	7	HS
5310	Orgoja	160	160	8.33	1	R
5316	Nonamurchi	155	152	55.00	7	HS
5319	Gandhakusturi	152	139	65.00	7	HS
5327	Huglapata	154	147	73.33	9	HS
5329	Gota	151	152	57.66	7	HS
5330	Dorkumur	159	153	41.66	5	MT
5337	Changi	151	151	55.66	7	HS
5345	Rasasail	159	113	62.33	7	HS
5347	Sackhorkhana	153	128	53.66	7	HS
--	BR11	145	115	83.00	9	HS
LSD (P=0.05)						

MT=Moderately tolerant, HS=Highly susceptible, R=Resistant.

Table 3. Yield and 1000 grain weight (TGW) of screened germplasms against ShB due to artificial inoculation of *Rhizoctonia solani* through hill inoculation in the field.

Acc. no.	Variety	TGW (g)	Yield (g hill-1)
4111	Gopal ghosh	20.13	6.92
4112	Chata bazail	21.14	8.17
4113	Ram dash	24.63	9.05
4114	Paizra	25.05	9.60
4118	Kala binni	29.11	10.05
4149	Beto	20.38	18.23
4155	Chini kani	9.19	5.30
4156	Minki	29.27	6.32
4162	Kasrail	26.14	14.55
4163	Khazur chari	21.44	7.24
4239	Binni	10.22	8.22
4267	Birpala	20.33	10.92
4271	Rayda	24.37	18.15
4272	Dhaki rayda	12.40	10.36
4768	Kaijhuri	29.16	10.28
4773	Dudhsail	14.03	10.07
4777	Kashra	16.05	4.85

Table 3. Continued.

Acc. no.	Variety	TGW (g)	Yield (g hill-1)
4778	Katarangi	13.33	8.40
4792	Basi	15.55	10.18
4793	Sada pankaich	16.26	12.56
4794	Kalahati	12.89	11.03
4795	Khajur chhori	15.19	10.59
4849	Rayeda	12.30	5.82
5121	Jamni	20.49	11.91
5122	Chaula maghi	26.87	16.03
5190	Bushi hara (mota)	27.06	5.55
5192	Lohamugra	27.12	10.17
5193	Chaula mari	21.44	7.24
5194	Kalagora	10.22	8.22
5195	Patjait	20.33	10.92
5196	Holdemota	19.37	10.15
5197	Kanchachikon	12.40	10.36
5198	Dholeshwar mota	29.16	10.28
5199	Calendamota	16.05	4.85
5212	Semmua	13.33	8.40
5213	Kotijira	15.55	10.18
5217	Ashkor	16.26	12.56
5218	Baskor	12.89	11.03
5219	Halisail	21.14	8.17
5220	Horakani	24.63	9.05
5221	Kalisura	25.05	9.60
5222	Akra	29.11	10.05
5223	Ushi har	20.38	18.23
5250	Ashfuli	9.19	5.30
5286	Ranisalut	20.33	10.92
5289	Buripagli	24.37	18.15
5298	Harisankar	12.40	10.36
5300	Birinde	29.16	10.28
5310	Orgoja	10.05	4.85
5316	Nonamurchi	12.30	5.82
5319	Gandhakusturi	20.49	11.91
5327	Huglapata	11.87	5.40
5329	Gota	27.06	5.55
5330	Dorkumur	27.12	10.17
5337	Changi	12.40	10.36
5345	Rasasail	29.16	10.28
5347	Sackhorkhana	16.05	4.85
--	BR11	23.98	13.98
LSD (P=0.05)		0.83	0.76

Table 4 shows that Orgoja was resistant against ShB disease of rice with the minimum RLH (11.66%) and severity score (1), whereas Gopal gosh was moderately tolerant to ShB with 40.56% RLH and severity score 5 through detached sheath inoculation method in test tube. But, rest of the germplasms with RLH ranging from 48.33 to 89.66% along with BR11 (90.68%) (Fig. 2) were found highly susceptible against ShB. Comparing the two inoculation method (*i.e.* hill inoculation and detached sheath inoculation) Orgoja was found as resistant and Gopal ghosh as moderately tolerant to ShB disease. In detached sheath inoculation method in test tube, most of the germplasms were found highly susceptible to ShB except Orgoja and Gopal ghosh. Dorkumur was found moderately tolerant in field condition but it showed high level of susceptibility to ShB in case of detached sheath

Table 4. Reaction of screened germplasms against ShB due to artificial inoculation of *Rhizoctonia solani* through detached sheath inoculation in test tube.

Acc. no.	Variety	RLH (%)	SES score	Reaction
4111	Gopal ghosh	40.56	5	MT
4112	Chata bazail	70.33	9	HS
4113	Ram dash	60.00	7	HS
4114	Paizra	74.33	9	HS
4118	Kala binni	72.33	9	HS
4149	Beto	82.66	9	HS
4155	Chini kani	61.66	7	HS
4156	Minki	67.33	9	HS
4162	Kasrail	58.00	7	HS
4163	Khazur chari	72.66	9	HS
4239	Binni	78.33	9	HS
4267	Birpala	68.00	9	HS
4271	Rayda	59.66	7	HS
4272	Dhaki rayda	72.33	9	HS
4768	Kaijhuri	63.00	7	HS
4773	Dudhsail	69.00	9	HS
4777	Kashra	53.00	7	HS
4778	Katarangi	57.33	7	HS
4792	Basi	75.33	9	HS
4793	Sada pankaich	65.66	9	HS
4794	Kalahati	75.00	9	HS
4795	Khajur chhori	67.33	9	HS
4849	Rayeda	69.66	9	HS
5121	Jamni	64.66	7	HS
5122	Chaula maghi	63.33	7	HS
5190	Bushi hara (mota)	56.00	7	HS
5192	Lohamugra	65.33	7	HS
5193	Chaula mari	72.66	9	HS
5194	Kalagora	65.66	9	HS
5195	Patjait	63.33	7	HS
5196	Holdemota	81.33	9	HS
5197	Kanchachikon	73.66	9	HS
5198	Dholeshwar mota	83.00	9	HS
5199	Calendamota	66.33	9	HS
5212	Semmua	78.00	9	HS
5213	Kotijira	76.33	9	HS
5217	Ashkor	55.33	7	HS
5218	Baskor	64.00	7	HS
5219	Halisail	66.00	9	HS
5220	Horakani	77.33	9	HS
5221	Kalisura	74.33	9	HS
5222	Akra	57.33	7	HS
5223	Ushi har	66.00	9	HS
5250	Ashfuli	75.00	9	HS
5286	Ranisalut	61.66	7	HS
5289	Buripagli	68.00	9	HS
5298	Harisankar	67.66	9	HS
5300	Birinde	84.66	9	HS
5310	Orgoja	11.66	1	R
5316	Nonamurchi	71.66	9	HS

Table 4. Continued.

Acc. no.	Variety	RLH (%)	SES score	Reaction
5319	Gandhakusturi	64.66	7	HS
5327	Huglapata	76.66	9	HS
5329	Gota	89.66	9	HS
5330	Dorkumur	48.33	7	HS
5337	Changi	72.00	9	HS
5345	Rasasail	62.33	7	HS
5347	Sackhorkhana	57.33	9	HS
--	BR11	90.66	9	HS
LSD (P=0.05)		17.52		

MT=Moderately tolerant, HS=Highly susceptible, R=Resistant.

inoculation method (Fig. 2). In general, dwarf, short duration and photo insensitive varieties were more susceptible to ShB. Prasad and Eizenga (2008) tested 73 *Oryza* genotypes for identifying resistant sources. They found only seven accessions moderately resistant to ShB. On the other hand, Moni (2012) found no resistant variety against ShB.

a) BR11 b) Dorkumur

Fig. 2. ShB symptoms of BR11 and Dorkumur due to artificial inoculation of *Rhizoctonia solani* through detached sheath inoculation method in test tube.

Integrated management of ShB of rice

Table 5 shows that the integrated management packages of ShB of rice resulted profound effect. Relative lesion height (RLH) was the maximum (68%) in T_6 (Control). The minimum RLH was 8% in T_1 (FDR + 30 July planting + Potash (K) fertilizer (202 g decimal^{-1}) + top dressing of urea (247 kg ha^{-1}) in four equal splits at 15 days interval + single spray of fungicide) and T_3 (K-dose + top dressing of urea in four equal splits at 15 days interval + single spray of fungicide). RLH was significantly different in different treatment combinations. T_2 (30 July planting + K-dose + top dressing of urea in four equal splits at 15 days interval + single spray of fungicide) and T_3 (K-dose + top dressing of urea in four equal splits at 15 days interval + single spray of fungicide) significantly differed in RLH. T_4 (Top dressing of urea in four equal splits at 15 days interval + single spray of fungicide) and T_5 (Single spray of fungicide) was different in RLH. Difference between T_3 and T_4 in RLH was also significant. There was significant difference in PDI (Percent disease index) among the treatment combinations. The maximum PDI was 69% in T_6 and the minimum 5% in T_1. T_2 and T_3 also differed significantly. Similarly, PDI of T_4 differed significantly from that of T_5. Moreover, tiller infection was 5% in T_1 which was significantly different from T_2 with 17%. T_3 and T_4 were also different in tiller infection. There was 25% tiller infection in T_4 and 39% in T_5. The maximum tiller infection was 86% in T_6. Besides, hill infection was 79% in T_6 (Control) as compared to 47% in T_5 (Single spray of fungicide). The difference was significant. In T_1 only 3% of the hills became infected, but it was 15% in T_2, 19% in T_3 and 35% in T_4 and all the treatments differed significantly.

Table 5. Effect of integrated disease management (IDM) on ShB of BR11 rice variety during T. Aman 2013.

Treatment	RLH (%)	PDI (%)	Tiller infection (%)	Hill infection (%)
T_1	8f	5f	5f	3f
T_2	17e	16e	17e	15e
T_3	23d	25d	21d	19d
T_4	36c	39c	25c	35c
T_5	49b	51b	39b	47b
T_6	68a	69a	86a	79a

Means followed by the same letter in a column did not differ significantly at the 5% level by LSD.

Table 6 shows that the effect of integrated management of ShB on yield and yield components. The maximum number of panicles per m^2 was recorded in T_1 (260) and the minimum in T_6 (Control) (227). There was no difference between T_5 (231) and T_6. However, the number of panicles per m^2 was 251 in T_2, 245 in T_3, 238 in T_4 and 231 in T_5 and all the treatments differed significantly. Number of filled grains per panicle was also significantly different in different treatments. It was 150 and 145 in T_1 and T_2. The minimum number of filled grains per panicle was recorded in T_6 (120) which differed significantly for that in T_5 (125). Significant difference was also observed between T_3 (139) and T_4 (131). Number of unfilled grains was the lowest in T_1 and the maximum in T_6. Significant difference was also observed between T_3 and T_4 as well as T_5 and T_6. Similarly, difference between T_4 and T_5 was also significant in number of unfilled grains per panicle. But there was no effect of integrated management of ShB on grain size. Weight of 1000 grain was 20 g in all treatments. Significant difference was observed between the treatments in grain yield of rice due to integrated management of ShB disease. The maximum yield was recorded in T_1 (6.3 t ha^{-1}) and the minimum in T_6 (3.6 t ha^{-1}). Yield was 6.0 t ha^{-1} in T_2 as compared to 5.5 t ha^{-1} in T_3 and the difference was significant. Similarly, T_4 produced 5.2 t ha^{-1} which was significantly lower than that of T_5 (4.5).

Finally, the present study revealed that the best IDM package was T_1 which included removal of floating debris, transplanting on 30 July, potash (K) fertilizer (202 g $decimal^{-1}$), urea top dressing (247 kg ha^{-1}) in four equal splits at 15 days interval and single spray of Azoxystrobin (10%) + Tebuconazole (90%) combination. Because, the maximum RLH, PDI, tiller infection and hill infection were found in control plot (T_6), whereas it was lower in the IDM packages and minimum in T_1 plot. Grain yield was also significantly higher in the IDM plots due to minimum incidence of ShB. Because, ShB was very low and grain yield was maximum in the plots where IDM was applied against ShB of rice due to its trace infection. Therefore, it can be concluded that the IDM package (T_1) though highly effective to control ShB of rice, but the result needs validation across the ecosystem. However, *Rhizoctonia solani* is an universal soil borne facultative and epidemic pathogen. The pathogen is difficult to control unless control measure is taken on time. Many scientists narrated that a single method of control is not effective in most cases to control ShB but IDM is recommended by the researchers (Mew *et al.*, 2004). Host resistance is a sustainable and economic method but there is no such resistant cultivar (Groth *et al.*, 1993). Antagonist such as *Trichoderma* may be a good option to include in IDM package (Dey *et al.*, 2004). ShB infection at flowering stage reduce grain yield due to higher amount of unfilled grains (Cu *et al.*, 1996) as because of damage of leaf sheath by the disease, affect water and nutrients supply to the growing spikelets (Lee and Rush, 1983).

Table 6. Effect of IDM on yield and yield components of BR11 during T. Aman 2013.

Treatment	Panicle per m^2	Filled grain $panicle^{-1}$	Sterile pikelet $panicle^{-1}$	TGW (g)	Yield (t ha^{-1})
T_1	260a	150a	40f	20	6.25a
T_2	251b	145b	47e	20	6.00b
T_3	245c	139c	53d	20	5.52c
T_4	238d	131c	61c	20	5.15d
T_5	231e	125d	67b	20	4.49e
T_6	227e	120e	61a	20	3.60f
Significance	*	*			*
CV (%)	5.15	8.65	18.40	0.0	19.16
LSD 0.05	4.00	3.50	4.90	NS	0.22

Means followed by the same letter did not differ at the 5% level by LSD. NS=Not significant. TGW=1000 grain weight

CONCLUSIONS

ShB of rice is considered as one of the major constraints of rice production in Bangladesh. Almost all HYVs and hybrid varieties are susceptible to the disease. Method for controlling the disease is an urgent need. Among the 57 germplasms, the local cultivar Orgoja (acc. no. 5310) showed resistance to ShB in both hill inoculation in field and detached sheath inoculation in test tube, which could be used in resistance breeding for varietal improvement programme of rice. On the other hand, the best integrated disease management (IDM) package was T_1 which included removal of floating debris, transplanting on 30 July, potash (K) fertilizer (202 g decimal^{-1}), top dressing of urea (247 kg ha^{-1}) in four equal splits at 15 days interval and single spray of Azoxystrobin (10%) + Tebuconazole (90%) combination. Because, ShB was very low and grain yield was high in the plots where T_1 package was applied. Therefore, it can be concluded that the IDM package (T_1) though highly effective to control ShB of rice, but the result needs validation in the farmer's field in different seasons with different rice varieties across the different AEZs of Bangladesh.

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Morphological Characterization and Diversity of T. Aman Rice Germplasm of Bangladesh

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ABSTRACT

Fifty-four T. Aman rice landraces were studied for 11 morphological and yield contributing characters at Bangladesh Rice Research Institute during T. Aman 2016 season. The largest variation was observed for yield per hill with 53.6% CV, followed by 1000 grain weight (29.9), number of effective tillers per hill (22.8), culm diameter (18.8), leaf width (18.4), leaf length (18.1) and days to maturity (6.7) respectively. The longest leaf was recorded as 82.2 cm and that of culm diameter as 7.57 mm, grain length as 7.2 mm and LB ratio as 3.48. The shortest days to maturity (110 days) was observed in Kajal lata and plant height (86.6 cm) in Haijam. Indursail possessed the longest panicle (31.6 cm) and the highest yield per hill (24.3 g). Based on D^2 values, all the germplasm were grouped into 15 clusters using Mahalonobis D^2 statistic. The maximum numbers of germplasm (7) were grouped into the clusters IV with VI, whereas clusters III and XIII contained the minimum (1). The highest intra-cluster distance (1.0) was found in cluster II and the lowest (0.0) in clusters III and XIII, respectively. The inter-cluster D^2 values ranged from 19.2 to 0.6 indicating wide range of diversity among the germplasm. Cluster XIII showed the highest leaf length (82.2 cm) and culm diameter (6.5 mm), cluster IX the highest effective tillers per hill (13), cluster II the lowest days to maturity (117), cluster XV the highest grain length (6.1 mm) and cluster I the highest grain LB ratio (2.97), while cluster VIII showed the highest yield per hill (22.0 g), panicle length (28.8 cm) and 1000 grain weight (25.2 g), respectively. Finally, the germplasm under clusters VIII may be selected for crossing with the germplasm from clusters XIII, IX, II, XV and I for developing high yielding varieties with improved panicle length, effective tillers per hill, growth duration and grain type.

Key word: Morphology, genetic diversity, T. Aman, germplasm, Bangladesh

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of Bangladesh, as well as the half of the world's population. Rice is also a commodity of significance and the easiest food source in Bangladesh. The availability and its price are also a major determinant of the welfare of the least food-secure segment of the country. However, with an increasing global population, the demand for rice will continue to rise, which raises challenges for the breeding of high yielding rice cultivars (Zhang *et al.*, 2013).

Rice production at farmer's level is increasing day to day in Bangladesh due to the constant development of many promising varieties for different rice ecosystems. Consequently, this bridge between technology and farmer now make Bangladesh possible to achieve the self-sufficiency in food grain production.

Genetic diversity created in the farmers' fields over millennia, complemented by the diversity present in wild relatives of crops, provides the primary material for improving crop productivity through plant breeding (Upadhyaya *et al.*, 2008). The amount of genetic enrichment is reliant on the extent of genetic diversity inherent in a population (Kumbhar *et al.*, 2015). A reduction in germplasm diversity is an obstacle to plant breeding and reduce the tendency of plants to resist unfavourable environments (Xiyong *et al.*, 2012). Landraces of rice can contain some valuable alleles not common in modern germplasm (Pervaiz *et al.*, 2010).

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Genetic variation in plant material is the base for crop improvement (Iqbal *et al*., 2014). Any crop improvement programme depends on the utilization of germplasm. Evaluation and characterization of existing landraces of rice are important due to increasing needs of varietal improvement. The pool of genetic variation within a population is the basis for selection as well as for plant improvement. Before exploiting a population for trait improvement, it is necessary to understand the magnitude of variability in the population which is fundamental for genetic improvement in all crop species. Agro-morphological characterization of germplasm accessions is fundamental criteria in order to provide information of plants (Lin, 1991) for plant breeding programmes (Das and Ghosh, 2011). Agro-morphological traits, both qualitative and quantitative have been commonly and traditionally used to estimate relationships between genotypes (Goodman, 1972). Finally, Lahkar and Tanti (2017) studied the morphological variation of 22 aromatic rice landraces of Assam using five qualitative and seven quantitative traits and reported that in rice improvement programme characterization of landraces could help breeders to utilize appropriate characters. Though a number of transplanted Aman rice germplasm have existed in different agro-climatic conditions of Bangladesh but their characterization is not sufficient. Therefore, the objectives of the present study was to characterize using morphological traits of the local transplanted Aman rice germplasm of Bangladesh for providing useful informations in rice breeding programmes.

MATERIALS AND METHOD

Fifty-four newly collected rice landraces from BRRI Genebank were studied for genetic diversity through morphological characterization (Table 1). The experiment was conducted using a single row of 5.4 m long for each entry with a spacing of 25 × 20 cm between rows and plants respectively during T. Aman 2016 season at Genetic Resources and Seed Division, BRRI, Gazipur. The thirty-five-day-old single seedling was transplanted in randomized complete block design (RCBD) with three replications. All the fertilizers except N were applied @ 60:20:40:12 kg NPKS/ha at final land preparation. All fertilizers were applied in basal, except urea. Intercultural operations and pest control measures were taken as and when necessary.

Data were collected on leaf length (cm), leaf width (mm), culm diameter (mm), effective tillers per hill, panicle length (cm), plant height (cm), days to maturity (days), grain length (mm), grain LB ratio, 1000 grain weight (TGW) and yield per hill (g). Simple statistics (means, ranges etc.) was calculated to have an idea of the level of variation. The genetic diversity was studied following Rao (1952), which was originally developed by the generalized distance (D^2) as proposed by Mahalonobis (1936). The germplasm were grouped into clusters using canonical vector analysis. All the statistical analysis regarding diversity was carried out using the GENSTAT 5.5 software.

RESULTS AND DISCUSSION

Morphological characterization. Analysis of variance revealed that the 54 germplasm showed highly significant differences for all the 11 studied morphological characters. Table 2 presents the details of the characterization results. The largest variation was observed for yield per hill with 53.6% CV, followed by TGW (29.9), number of effective tillers per hill (22.8), culm diameter (18.8), leaf width (18.4), leaf length (18.1) and the smallest in days to maturity (6.7) respectively.

Table 1. List of rice germplasm characterized during T. Aman 2016.

Variety	Code*	Upazila	District	Variety	Code*	Upazila	District
Double rice	TA1	Kaliganj	Jhenaidah	Molla digha	TA28	Shibalaya	Manikganj
Tulshi mala	TA2	Fulpur	Mymensingh	Modhu sail	TA29	Shibalaya	Manikganj
Kajal lata	TA3	Jhikorgacha	Jashore	Indursail	TA30	Ulipur	Kurigram
Subal lata	TA4	Jhikorgacha	Jashore	Jira bhog	TA31	Vurangamari	Kurigram
Hb. Aman II (Lacki)	TA5	BRRI	Habiganj	Malshira	TA32	Vurangamari	Kurigram
Depor dhan	TA6	Nagarpur	Tangail	Khirshapal	TA33	Ulipur	Kurigram
Kalo parangi	TA7	Nagarpur	Tangail	Dudh kolom	TA34	Ulipur	Kurigram
Swarna	TA8	Nagarpur	Tangail	Narikel jhupi	TA35	Ulipur	Kurigram
Lalsaina	TA9	Nagarpur	Tangail	Urichadra	TA36	Ovainagar	Jashore
Jotalaijum	TA10	Nagarpur	Tangail	Ranga gasa	TA37	Ovainagar	Jashore
Dolni	TA11	Ghatail	Tangail	Sada gosa	TA38	Ovainagar	Jashore
Barai dhan	TA12	Ghatail	Tangail	Haringa digha	TA39	Mirzapur	Tangail
Chini sugar	TA13	Ghatail	Tangail	Bagraj	TA40	Kalihati	Tangail
Kalijira	TA14	Ghatail	Tangail	Begun bichi	TA41	Sadar	Tangail
Kiron mala	TA15	Ghatail	Tangail	Chamara (Lal)	TA42	Sadar	Tangail
Apsaya	TA16	Ghatail	Tangail	Kalijira	TA43	Sadar	Tangail
Chini kutei	TA17	Ghatail	Tangail	Patjak	TA44	Sadar	Tangail
Biropa	TA18	Sakhipur	Tangail	Nizersail	TA45	Sadar	Tangail
Gobra sail	TA19	Sakhipur	Tangail	Dulai	TA46	Sadar	Tangail
Gonokrai	TA20	Basail	Tangail	Haijam	TA47	Sadar	Tangail
Soma baila	TA21	Basail	Tangail	Digha	TA48	Sadar	Tangail
Dulai boron	TA22	Basail	Tangail	Aloi	TA49	Sadar	Tangail
Hari dhan	TA23	Basail	Tangail	Vaeulu	TA50	Nagarpur	Tangail
Kartikjul	TA24	Basail	Tangail	Heringa digha	TA51	Nagarpur	Tangail
Komkamane	TA25	Sakhipur	Tangail	Hejal digha	TA52	Nagarpur	Tangail
Ganokairot	TA26	Sakhipur	Tangail	Harharia	TA53	Nagarpur	Tangail
Bela digha	TA27	Shibalaya	Manikganj	Sada vara	TA54	Nagarpur	Tangail

*New collection.

On the other hand, 26 germplasm possessed intermediate (6-10), 27 possessed many (>10) and one had few (<6) number of effective tillers (Table 2). One germplasm was found with very long (>30 cm), 11 with long (26-30), 38 with medium (21-25) and four had short (≤20) panicle length. Three germplasm were found with short (<110 cm), 11 with moderate (110-130) and 40 with long (>130) plant height. Thirteen germplasm had short (<120 days), seven had medium (120-130) and 34 had long (>130) days to maturity. Besides, 20 germplasm were found with short (<5.6 mm), 33 with medium (5.6-6.5) and one with long (6.6-7.5) types of grain. Rice grain can also be classified as extra-long, long, medium and short (Bisne *et al.*, 2006). Considering length-breadth ratio, 12 germplasm were found with bold (1.5-2.0), 34 with medium (2.1-2.5) and four each with medium slender (2.6-3.0) and slender (>3.0) grain. TGW of 14 germplasm was found very low (<16 g), 10 with low (16-19), 19 with medium (20-23), eight with high (24-27) and three had very high (>27). Eleven germplasm possessed low (<5 g), 26 had moderate (5-10) and 17 had higher (>10) yields per hill. Maji and Shaibu (2012) reported a wider range (70-184 cm) of variation with a mean value of 151.15 cm in plant height. Plant height in rice is a complex character and is the end product of several genetically controlled factors called internodes (Sarawgi and Rastogi, 2000). Reduction in plant height may improve their resistance to lodging and reduce substantial yield losses associated with this trait (Pachauri *et al.*, 2017a). Pachauri *et al.* (2017b) studied 124 rice germplasm accessions on the basis of 19 morphological characters and reported that a great variability with high range (5-26) and mean of 8.20 was exhibited for number of productive tillers per plant, while high range (86-130 days) with mean of 111.33 days for days to maturity.

However, the shortest growth duration (110 days) was observed in Kajal lata and the longest (143) in Ranga and Sada gasa in the present study. The shortest plant height (86.6 cm) was observed in Haijam and the longest (168) in Gobra sail. Indursail possessed the longest panicle (31.6 cm). Malshira was found with the highest number of effective tillers (18) and Harharia with the lowest (2). The highest grain length-breadth ratio (3.48) was observed in Subal lata and the lowest (1.89) in Vaeulu and Depor dhan. Komkamane had the lowest (8 g) and the Molla digha had the highest (31.2) TGW. The highest yield per hill (24.26 g) was observed in Indursail and the lowest (2.48) in Biropa. Table 3 presents the top ranking accessions for yield ancillary traits in T. Aman 2016. Abarshahr *et al.* (2011) also found valuable and highly significant and positive variability among their studied rice genotypes. Besides, Sajid *et al.* (2015) also reported that characterization of rice germplasm through different morphological traits is an important step for assessment of its genetic potential.

Principal component analysis. The first four components in principal component analysis with eigen values >1, contributed 68.78% of the total variation among the 54 germplasm for 11 morphological characters (Table 4). Chakravorty *et al.* (2013) also observed the contribution of 75.9% of the first four components to the total variation in rice.

Cluster analysis. Based on D^2 values, the germplasm were grouped into 15 clusters using Mahalonobis D^2 statistic (Table 5). Mahalingam *et al.* (2012) also observed 13 clusters in 31 Indian and exotics germplasm lines. Maximum numbers of germplasm (7) were grouped into the clusters IV and VII, followed by 6 in clusters V and II, 5 in cluster IX. However, clusters III and XIII contained the lowest (1) number of germplasm. The result revealed that all the germplasm collected from Tangail or Kurigram district were not clubbed into the same cluster. This pattern of clustering indicated that there was no association between the geographical distribution of genotypes and genetic divergence. The similar result was also reported earlier by Chandra *et al.* (2007). Considering this, Hasan *et al.* (2000) suggested that parents should be selected on the basis of genetic diversity rather than geographic diversity.

Table 6 indicates the variations among the intra and inter cluster distances. All the inter-cluster distances were larger than the intra-cluster distance indicating the homogeneous nature of the germplasm within the cluster. The highest intra-cluster distance was recorded for cluster II (1.00), followed by cluster I (0.83) and cluster XII (0.81) indicated the high genetic diversity among the germplasm belonging to the respective cluster. The germplasm belonging to the highest intra-cluster distance (cluster II) were the most heterogeneous and might develop the highest segregants by crossing between them. Again, there were marked variations in intra-cluster

Table 2. Some important features of characterized germplasm during T. Aman 2016.

LL		LW		CD		ETPH		PL		PH		DM		GL		LBR		TGW		YPH	
R	NE	R	NE	R	NE	R	NE	R	NE	R	NE	R	NE	R	NE	R	NE	R	NE	R	NE
<40	4	<10	3	<4	4	<6	1	≤20	4	<110	3	<120	13	<5.6	20	<1.5	0	<16	14	<5	11
40-59	38	10-12	26	4-5	37	6-10	26	21-25	38	110-30	11	120-30	7	5.6-6.5	33	1.5-2.0	12	16-19	10	5-10	26
60-79	11	13-16	21	6-7	12	>10	27	26-30	11	>130	40	>130	34	6.6-7.5	1	2.1-2.5	34	20-23	19	>10	17
>79	1	>16	4	>7	1			>30	1					>7.5	0	2.6-3.0	4	24-27	8		
																>3.0	4	>27	3		
Shortest (25.2)	Double rice	Lowest (7)	Kalijira	Longest (3.05)	kajallata	Lowest (2)	Harharia	Shortest (16)	Double rice	Shortest (86.6)	Haijam	Shortest (110)	Kajallata	Lowest (3.68)	Chini sugar	Lowest (1.89)	Vaeulu, Depor dhan	Lowest (8.0)	Komka mane	Lowest (2.5)	Biropa
Longest (82.2)	Sada gasa	Highest (18)	Nizersail	Highest (7.57)	Dulai	Highest (18)	Malshira	Longest (31.6)	Indursail	Longest (168)	Gobra sail	Longest (143)	Ranga and Sadagasa	Highest (7.2)	Dudh kolom	Highest (3.48)	Suballata	Highest (31.2)	Molla digha	Highest (24.3)	Indur sail
Mean	52.5	12.8		5.2		10		24.3		138.9		129		5.5		2.3		19.6		8.9	
Std. Dev.	9.5	2.4		1.0		2.4		2.7		20.0		8.6		0.7		0.4		5.8		4.8	
CV	18.1	18.4		18.8		22.8		11.3		14.4		6.7		12.2		15.4		29.9		53.6	
LSD	2.5	0.6		0.3		0.6		0.7		5.3		2.3		0.2		0.1		1.5		1.3	

LL=Leaf length (cm), LW=Leaf width (mm), CD=Culm diameter (mm), ETPH=Effective tillers per hill, PL= Panicle length (cm), PH=Plant height (cm), DM=Days to maturity (days), GL=Grain length (mm), LBR=Grain LB ratio, TGW=1000 grain weight (g), YPH= Yield per hill (g), R= Range and NE= No. of entries.

Table 3. Top ten ranking germplasm for different yield ancillary traits in T. Aman 2016.

Panicle length (cm)	Plant height (cm)	Time of maturity (day)	Effective tillers per hill	Grain length breath ratio	1000 grain weight (g)	Yield per hill (g)
Indursail (TA30)-31.6*	Haijam (TA47)-86.6	Kajal lata (TA3)-110	Malshira (TA32)-18.2	Subal lata (TA4)-3.48	Molla digha (TA28)-31.2	Indursail (TA30)-24.3
Lalsaina (TA9)-29.4	Subal lata (TA4)-88	Subal lata (TA4)-112	Khirshapal (TA33)-15.8	Kajal lata (TA3)-3.44	Sada vara (TA54)-30.3	Kartikjul (TA24)-19.9
Kartikjul (TA24)-29.0	Kajal lata (TA3)-89.8	Harharia (TA53)-112	Dudh kolom (TA34)-15.6	Kalijira (TA43)-3.21	Modhu sail (TA29)-28.9	Gobra sail (TA19)-19.7
Dolni (TA11)-28.0	Chini kutei (TA17)-115.2	Hejal digha (TA52)-117	Apsaya (TA16)-14.0	Dudh kolom (TA34)-3.08	Kartikjul (TA24)-26.9	Narikel jhupi (TA35)-19
Barai dhan (TA12)-28.0	Hari dhan (TA23)-116.4	Depor dhan (TA6)-118	Jira bhog (TA31)-14.0	Double rice (TA1)-2.87	Patjak (TA44)-26.2	Ranga gasa (TA37)-15.7
Jira bhog (TA31)-28.0	Chini sugar (TA13)-117	Kalo parangi (TA7)-118	Chamara (Lal) (TA42)-12.6	Jotalaijum (TA10)-2.67	Ranga gasa (TA37)-26.0	Hari dhan (TA23)-15.6
Sada vara (TA54)-27.8	Dolni (TA11)-163.0	Biropa (TA18)-118	Alcii (TA49)-12.6	Nizersail (TA45)-2.62	Depor dhan (TA6)-25.6	Barai dhan (TA12)-14.8
Begun bichi (TA41)-27.6	Sada vara (TA54)-166.0	Dulai boron (TA22)-118	Lalsaina (TA9)-12.4	Barai dhan (TA12)-2.60	Indursail (TA30)-25.5	Malshira (TA32)-14.2
Sada gasa (TA38)-27.2	Sada gasa (TA38)-167.8	Bela digha (TA27)-118	Hb. Aman II (Lacki) (TA5)-12.2	Apsaya (TA16)-2.57	Gobra sail (TA19)-24.9	Molla digha (TA28)-13.9
Biropa (TA18)-26.2	Gobra sail (TA19)-168.0	Molla digha (TA28)-118	Somo (TA8)-12	Dulai (TA46)-2.53	Hari dhan (TA23)-24.2	Sada gasa (TA38)-12.7

*local name (code name)-value

Table 4. Latent roots (eigen value) and their variation for 11 morphological characters of 54 T. Aman rice germplasm.

Principal Component	Latent roots	Variation accounted (%)	Cumulative Variation (%)
I	2.83	25.75	25.75
II	2.22	20.21	45.96
III	1.49	13.55	59.51
IV	1.02	9.27	68.78
V	0.91	8.27	77.05
VI	0.62	5.64	82.69
VII	0.58	5.25	87.94
VIII	0.54	4.9	92.84
IX	0.46	4.18	97.02
X	0.27	2.46	99.48
XI	0.06	0.53	100.01

Table 5. Distribution of 54 T. Aman rice germplasm into 15 clusters for 11 morphological characters.

Cluster	No. of germplasm	Code name of the germplasm
I	3	TA3, TA4, TA47
II	6	TA18, TA21, TA22, TA27, TA28, TA53
III	1	TA15
IV	7	TA2, TA12, TA14, TA16, TA31, TA41, TA43
V	6	TA6, TA20, TA24, TA42, TA45, TA54
VI	7	TA5, TA7, TA26, TA48, TA50, TA51,TA52
VII	2	TA1, TA36
VIII	2	TA19, TA30
IX	5	TA13, TA17, TA25, TA32, TA33
X	3	TA10, TA35, TA46
XI	3	TA9, TA44, TA49
XII	2	TA11, TA40
XIII	1	TA38
XIV	2	TA23, TA37
XV	4	TA8, TA29, TA34, TA39

Table 6. Average intra-(bold) and inter-cluster distances (D^2) for 11 morphological characters of 54 T. Aman rice germplasm.

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
I	**0.83**														
II	9.9	**1.0**													
III	12.5	8.3	**0.0**												
IV	11.4	7.1	1.3	**0.68**											
V	14.4	5.0	7.5	6.9	**0.71**										
VI	10.7	1.0	7.9	6.7	4.0	**0.57**									
VII	7.0	4.7	6.1	4.8	7.9	5.1	**0.64**								
VIII	18.3	9.4	8.3	8.3	4.6	8.5	11.3	**0.39**							
IX	7.3	8.1	5.6	4.8	10.4	8.3	3.4	12.9	**0.74**						
X	9.8	4.3	4.2	2.9	5.5	4.0	2.8	8.6	4.9	**0.75**					
XI	13.4	5.5	4.6	4.1	2.9	4.7	6.4	4.9	8.2	3.6	**0.57**				
XII	19.1	10.4	8.7	8.9	5.5	9.4	12.1	1.0	13.6	9.3	5.7	**0.81**			
XIII	19.2	11.2	7.9	8.4	6.7	10.3	12.2	2.6	13.2	9.4	6.0	1.9	**0.0**		
XIV	7.5	4.9	5.5	4.2	7.7	5.2	0.6	11.0	3.2	2.4	6.0	11.7	11.8	**0.33**	
XV	11.7	3.4	5.5	4.5	3.1	2.7	4.9	6.7	7.4	2.5	2.1	7.5	8.0	4.7	**0.68**

distances indicating the presence of wider diversity among the germplasm of different clusters. However, the lowest intra-cluster distance were observed in clusters III and XIII as zero due to the presence of single genotype in both the clusters (TA15 and TA38 respectively), followed by cluster XIV (0.33) and cluster VIII (0.39) indicating the comparatively more homogenous in nature of the germplasm. The inter-cluster D^2 values ranged from 19.2 to 0.6 indicating wide range of diversity. The highest inter-cluster distance was observed between clusters I and XIII (19.2) suggested wide diversity between these clusters, followed by between clusters I and XII (19.1), clusters I and VIII (18.3), clusters I and V (14.4) and clusters IX and XII (13.6). The lowest inter-cluster distance was observed between clusters VII and XIV (0.60), followed by clusters VI and X (2.55) and clusters II and VI (1.0) indicating the close relationship between the germplasm of these clusters and hence, may not be emphasized upon to be crossed each other in hybridization programmes. Hossain (2008) also reported intra- and inter-cluster distances ranged from 0.0 to 1.02 and 2.21 to 21.59, respectively on aromatic and fine grain landraces of rice. However, germplasm belonging to these clusters may be further used in hybridization programme for the improvement of rice. Crosses involving parents belonging to the most divergent clusters would be expected to manifest maximum heterosis and wide variability of genetic architecture (Souroush *et al.*, 2004).

Cluster means for the characters. Cluster XIII showed the highest leaf length (82.2 cm) and culm diameter (6.5 mm), cluster IX the highest number of effective tillers per hill (13), cluster II the lowest days to maturity (117), cluster XV the highest grain length (6.1 mm) and cluster I the highest grain LB ratio (2.97) respectively, while cluster VIII showed the highest yield per hill (22.0 g), panicle length (28.8 cm) and 1000 grain weight (25.2 g) (Table 7). As a result, the germplasm under cluster VIII may be selected for crossing with the germplasm from clusters XIII, IX, II, XV and I for developing high yielding T. Aman variety along with long panicle, high effective tiller numbers per hill, short growth duration and long-slender type grain. Islam *et. al.* (2017) earlier also reported the similar trend of conclusion using Mahalanobis' D^2 statistic on rice.

Canonical variate analysis. In the present study, it also appeared from the canonical analysis that 52.51% of the total variation was accounted for canonical root 1 and 19.88% by canonical root 2 (Table 8).

Contribution of characters towards divergence. Table 9 presents the coefficients pertaining to the different characters in the first two canonical roots. The canonical variate analysis revealed that the grain LB ratio, culm diameter, effective tillers per hill, panicle length and days to maturity were positive for both the vectors (I and II) and were the most responsible for both the primary and secondary differentiations and contributed maximum to the genetic divergence. Such results indicated that these characters will offer a scope for selection of parents. Similarly, Islam *et al.* (2017) also found positive contribution of both canonical vectors for culm diameter, days to flowering, days to maturity and length-breadth ratio on Jhum rice landraces collected from Rangamati district in Bangladesh.

Table 7. Cluster means of 54 T. Aman rice germplasm for 11 morphological and yield contributing characters.

Cluster	Leaf length (cm)	Leaf width (mm)	Culm diameter (mm)	Effective tillers per hill	Panicle length (cm)	Plant height (cm)	Day to maturity	Grain length (mm)	Grain LB ratio	1000 grain weight (g)	Yield per hill (g)
I	46.8	11.7	4.2	10	23.7	88.1	119	5.9	2.97	17.3	6.4
II	47.1	13.8	5.3	8	23.7	132.7	117	5.7	2.17	22.3	6.37
III	33.0	11.0	5.1	11	24.4	154.4	139	4.1	2.10	9.5	6.3
IV	52.9	10.9	4.8	12	26.0	142.4	135	4.9	2.47	12.4	8.9
V	58.2	15.8	6.0	11	25.6	156.9	125	6.0	2.23	23.9	10.9
VI	55.9	14.9	5.2	10	21.9	135.6	121	5.6	2.14	21.3	6.33
VII	30.6	10.5	4.6	9	19.2	125.7	133	5.7	2.45	21.8	7.9
VIII	61.5	13.5	4.5	10	28.8	172.3	133	5.7	2.10	25.2	22.0
IX	44.5	11.2	5.0	13	23.6	122.6	135	4.6	2.36	11.1	8.4
X	62.3	12.7	6.2	11	23.7	130.7	133	5.8	2.40	20.7	13.0
XI	65.4	11.2	5.5	12	25.7	147.1	137	6.0	2.23	23.8	8.8
XII	49.5	11.7	5.3	11	25.3	182.9	133	5.5	2.25	16.0	6.4
XIII	82.2	11.0	6.5	8	27.2	167.8	143	5.3	2.10	22.7	12.7
XIV	47.0	12.4	4.5	10	23.0	120.7	142	5.9	2.20	25.1	15.6
XV	51.1	12.8	5.2	11	24.2	144.8	133	6.1	2.40	23.7	4.7

Table 8. Values of latent roots (canonical roots) and percentage of variation of 11 morphological characters of 54 T. Aman rice germplasm.

Canonical root	Value of the canonical root	Percentage of variation absorbed by the canonical root
1	24.54	52.51
2	9.29	19.88
3	6.35	13.59
4	3.73	7.98
5	1.22	2.60
6	0.69	1.47
7	0.37	0.79
8	0.23	0.50
9	0.17	0.35
10	0.11	0.23
11	0.04	0.09
Total		100.0

Table 9. Latent vectors for 11 morphological characters of 54 T. Aman rice germplasm.

Character	Vector I	Vector II	Combined ranking*
Leaf length (cm)	-0.0851	-0.0104	8
Leaf width (mm)	0.0851	-0.2458	9
Culm diameter (mm)	0.2782	0.4546	2
Effective tillers per hill	0.183	0.0856	3
Panicle length (cm)	0.0884	0.1272	4
Plant height (cm)	-0.1961	0.0167	10
Days to maturity	0.0138	0.1515	5
Grain length (mm)	-1.2476	-2.1051	11
Grain LB ratio	1.8633	2.9192	1
1000 grain weight (g)	0.0413	-0.0153	7
Yield per hill (g)	-0.0121	0.0787	6

*Combined ranking is estimated by summing the values of vector I and II, then higher (1) is the rank with higher positive value.

CONCLUSIONS

Since the modern variety with the narrow genetic base are vulnerable to diseases and adverse climatic changes, the genetically diverse genotypes for variety development become more important. Moreover, characterization of landraces could help to utilize appropriate characters in rice improvement programme. Indursail (TA30), Kartikjul (TA24), Kajal lata (TA3) and Subal lata (TA4) are the elite germplasm promising for one or more characters. Finally, the germplasm under clusters VIII may be selected for crossing with the germplasm from clusters XIII, IX, II, XV and I for developing high yielding variety along with long panicle, high effective tiller numbers per hill, short growth duration and long-slender type grain.

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Moisture Stress and Different Rates of Nutrients on Growth and Yield of Rice

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ABSTRACT

The experiment was conducted at the Bangladesh Rice Research Institute (BRRI) Gazipur farm during Boro 2003-04 seasons to observe the moisture stress effects in relation to nutrient rates on growth and yield of rice. The treatments were three moisture stresses (NS= Always saturated condition i.e. 1-2 cm standing water; VPS= Withholding water at the vegetative phase i.e. 15 days after transplanting (DAT) to maximum tillering stage; RPS=Withholding water at the reproductive phase i.e. PI to flowering stage) and three fertilizer doses (F0= No fertilizer; HD= Half of the optimum dose and OD= Optimum dose i.e. 120-60-40-10-2 kg ha^{-1} of N, P_2O_5, K_2O, S and Zn respectively). The treatments were applied in high yielding variety BRRI dhan29. The result showed that irrespective of nutrient rates, drought stress decreased plant height, tiller number and shoot dry weight. Unstressed plants (NS) produced the highest grain yield (3.14 to 6.51 tha^{-1}) followed by vegetative phase stressed (VPS) plants (2.73 to 4.50 tha^{-1}). The reproductive phase stressed (RPS) plants produced the lowest grain yield (2.54 to 4.20 t ha^{-1}). Regardless of water stress, application of optimum dose (OD) of nutrients produced the highest grain yield followed by half dose (HD) of nutrients. No fertilizer treatment (F0) produced the lowest grain yield. Due to water stress, the highest grain yield reduction occurred in OD (22-32%) followed by HD (12-19%) and the lowest in F0 (4-15%).

Key words: Rice (*Oryza sativa* L.), moisture stress, nutrients rates, plant growth, yield and yield components

INTRODUCTION

Rice is the most important food crop for more than half of the world population, especially in developing countries such as Asia, where water scarcity and drought are imminent threats to food security. Rice supplies more than 50% of calorie and 75% of protein consumed by the people of the developing countries (Khush, 2005). Its flexibility and adaptation to natural conditions, rice is planted in about 113 countries of the world (Rice is life, 2005). Drought is the most important limiting factor for crop production and it has been increasing day by day and becoming a severe problem in many regions of the world. Most of the crops are sensitive to drought stress particularly during flowering to grain filling stage (Sabetfar *et al.*, 2013). Rice uses two to five times more water than other cereal food crops such as wheat or maize and uses about 30% of the freshwater used for agricultural crops worldwide. Water stress is the most important limiting factor for growing rice. About 1,100 to 1,200 litres of water is required to produce 1.0 kg rough rice (Rice is life, 2005). Sometimes it may increase up to 4,000 litres. Exploring the ways to reduce water use for rice production is therefore of great strategic value for sustainable crop production for the world facing water scarcity (Molden *et al.*, 2010). The plants anatomy, morphology, physiology and biochemistry as well as their growth and development also affected by drought stress (Heidary *et al.*, 2007). Under a water stress situation, root growth is less inhibited than shoot growth and the dry matter partitioning between

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root and shoot was altered depending on moisture availability (Blum *et al*., 1983; Penning de Vries *et al*., 1989).

Keller (2005) reported that water and nutrients exist together in close association because plant available nutrient ions are dissolved in the soil solution and nutrient uptake by plant roots depends on water flow through the soil-root-shoot pathway. Leaf transpiration generates the tension necessary for the roots to absorb this essential solution, but in a dry soil, uptake of water and nutrients becomes progressively more difficult for any crop. Viets (1972) observed that nutrient and water absorption are independent processes in root, the necessity for available water in both the plant and soil for growth and nutrient transport makes them closely related. This close relationship makes it complex to clearly define the effects of water stress on mineral nutrition. Slatyer (1969) stated that the effect of water stress on mineral nutrition is difficult to resolve clearly. The key point is whether or not reduced nutrient uptake retards growth and development in a plant under stress. It results in an increase of solute concentration outside the roots compared to the internal environment of the root and causes reverse osmosis. As a result, the cell membrane shrinks from the cell wall and may eventually lead to death of the cell. Moisture stress inhibits photosynthesis in plants by closing stomata and damaging the chlorophyll contents and photosynthetic apparatus (Waraich *et al*., 2011).

Drought stress at vegetative phase of rice had minor effect on subsequent growth and grain yield. The reduction of grain yield was upto 30% due to decrease in panicle number in one trial and reduced spikelet number in another trial (Boonjung and Fukai,1996). They also reported that water stress at panicle development stage decreased grain yield due to delayed anthesis and the number of spikelets per panicle reduced upto 60% compared to control and the percentage of filled grains decreased upto to zero. The decrease in grain yield is associated with low dry matter production during the drought period as well as during the recovery period following the drought (Halder and Burrage, 2003). Drought stress at an early seedling stage may cause wilting, rolling, and drying of leaves (Murty and Ramakrishnayya, 1982). Water stress at the tillering stage reduces plant height, tiller number and leaf area. It induces leaf rolling, drying and premature leaf death and prolongs the vegetative stage (IRRI, 1976; Lee *et al*., 1994). The effects may occur even after stress has been eliminated (Jana and Ghildyal, 1972; O' Toole and Cruz, 1979). Cruz *et al*., (1986) found that mild water stress during vegetative growth decreased tiller and panicle number, leaf area, shoot and total dry matter mass. Castillo *et al*. (1987); BRRI (1991) reported that when water stress occurs during the vegetative phase, total dry matter production is decreased at harvest due to slow growth and the production of a smaller number of tillers.

Drought stress during the reproductive growth affects essentially all aspects of rice growth and development (Sharma *et al*., 1987; Okada, *et al*., 2002; Tuong *et al*., 2002). Depending on the severity and duration, early water deficit induces leaf rolling, drying, reduced photosynthetic activity, leaf water potential, plant height, leaf area, leaf number, dry matter yield, spikelet fertility, grain yield and delayed the onset of the reproductive growth period as well as delayed flowering and maturity (Yang *et al*., 1994; Tuong *et al*., 2002). When drought occurred during grain filling, the percentage of filled grains decreased to 40% and individual grain mass decreased by 20% (Boonjung and Fukai, 1996). Water stress in rice plant decreases the rate of photosynthesis that affects the number of tiller, leaf area, dry matter accumulation, filled grain per panicle, 1000 grain weight and grain yield (Halder and Burrage 2004; Zumber *et al*., 2007; Sabetfar *et. al*., 2013).

Information regarding the effect of moisture stress and different rates of nutrients on the growth, yield and yield components of rice is scanty. Therefore, this experiment was undertaken to investigate the effect of moisture stress and different doses of nutrients on the growth, yield and yield components of rice.

MATERIALS AND METHODS

The experiment was conducted at the BRRI farm Gazipur during Boro 2003-04 season. The treatments were three moisture stresses (NS= Always saturated condition i.e. 1-2 cm standing water; VPS= Withholding water at the vegetative phase i.e. 15 DAT to maximum tillering stage; RPS=Withholding water at the reproductive phase i.e. PI to flowering stage) and three fertilizer doses (F0= No fertilizer; HD= Half of the optimum dose and OD= Optimum dose i.e. 120-60-40-10-2 kg ha^{-1} of N, P_2O_5, K_2O, S and Zn, respectively). The treatments were arranged in a randomized complete block design (Factorial) with three replications. BRRI dhan29 was used as tested variety. The unit plot size was 4m × 4m. Thirty-five-day-old seedling @ 3 seedlings per hill was transplanted. The plant height, tiller number per hill and plant samples were collected from 15 days after transplanting (DAT) i.e. from stress imposed to maturity of the crop with 28 days intervals. The sampling days were D1= 0 days after stress imposed (DASI), D2=28 DASI, D3=56 DASI, D4=84 DASI and D5=112 DASI. At the maturity of the crop, the grain yield was recorded from 5-m^2 area excluding the border rows and weight was adjusted at 14% moisture content. The collected data were analyzed by following a standard statistical procedure and the mean differences were adjusted by LSD method.

RESULTS AND DISCUSSION

Plant height. Regardless of nutrient rates, water stress significantly ($P<0.05$) reduced plant height of vegetative phase stressed (VPS) plants (Fig. 1). At the end of the vegetative phase, when water stress was withdrawn from the VPS plants, there was a sharp increase of plant height but it could not reach reproductive phase stressed (RPS) plants. It was significantly ($P<0.05$) lower than the RPS plants. When water stress was imposed in the RPS plant, the plant height did not decrease significantly ($P>0.05$). The unstressed (NS) plants showed the highest plant height. IRRI (1976) reported that drought stress at vegetative and reproductive phase decreased plant height.

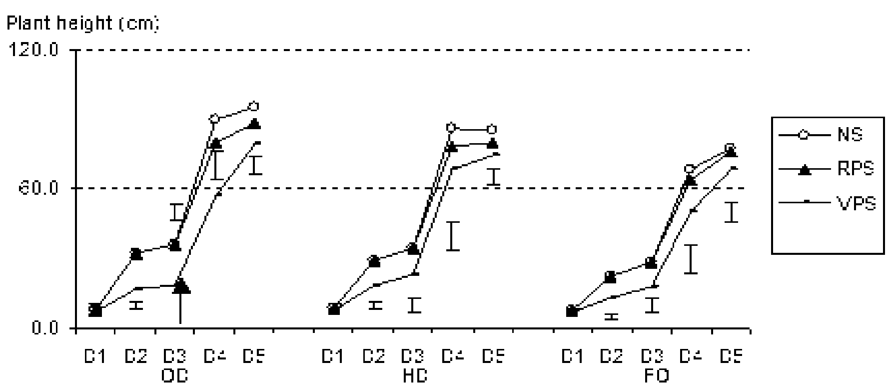

Fig. 1. Plant height as affected by nutrient rates and moisture stress throughout the experimental period. Arrow at D3 indicates the end of the VPS and start of RPS. (Vertical bars represent the LSD (0.05) value indicates the difference among the water stress under same level of nutrient rates and among the nutrient rates under same level of water stress.)

Tiller number. Regardless of nutrient rates, water stress significantly ($P<0.05$) reduced tiller number of vegetative phase stressed (VPS) plants (Fig. 2). Yoshida (1981) stated that in the vegetative phase, rice plants produced tillers from the leaf axils at each un-elongated node. Due to some environmental limitations such as water and nutrient supply, light etc. tiller production may be inhibited and all the tiller buds do not develop into tillers. At the end of the vegetative phase, there was a sharp increase of tiller number of VPS, plants however, it was significantly ($P<0.05$) lower than the RPS plants of OD. In HD and F0 it was not significantly lower ($P>0.05$) than OD. Yoshida (1981); Smith and Hamel (1991) observed that the tillering of rice depends on the nutritional status of the plant and tillering is highly impaired by a lack of N or P. The experiment here confirmed these findings; a larger number of tillers being produced by the plants grown in the higher nutrient i.e. OD. When water stress was imposed in the RPS plants, the tiller number did not decrease significantly ($P>0.05$). The unstressed (NS) plants had the highest tiller number. The tiller produced after vegetative phase was unproductive.

Shoot dry weight. Water stress significantly decreased the shoot dry weight under both vegetative phase and reproductive phases (Fig. 3). Dry weight increased after removal of water stress from vegetative phase stressed (VPS). However, it was lower than unstressed (NS) plants. Researchers reported that dry matter production decreased in water stressed plant also due to a reduction of cell turgidity, which affects cell expansion (Mengel and Kirkby, 1987; Hsiao, 1973) or alternatively might be due to both chemical and hydraulic signaling of the effects of soil drying (Davies *et al.*, 2000).

Table 1 shows that the interaction effect of drought stress and nutrient rates was significant ($P>0.05$) in yield and yield components except 1000-grains weight.

Panicle number. Irrespective of moisture stress, the highest number of panicles was observed in OD followed by HD but there was no significant difference between HD and OD. The lowest number of panicles was found in F0. Regardless of nutrient rates the NS plants produced the highest number of panicles. The lowest number of panicles was found in RPS plant under F0 and in VPS plants under HD and OD but there was no significant difference between VPS and RPS. Hsiao (1982) stated that water stress enhance the poor flowering and incomplete panicle exertion.

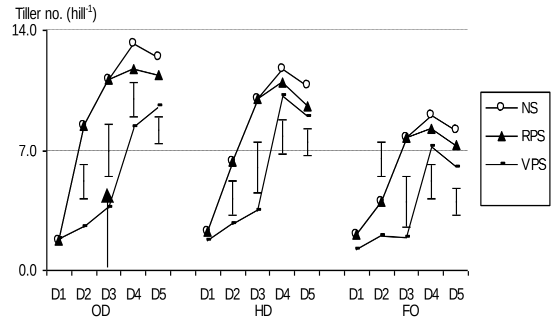

Fig. 2. Tiller number as affected by nutrient rates and drought stress throughout the experimental period. Arrow at D3 indicates the end of the VPS and start of RPS. (Vertical bars represent the LSD (0.05) value indicates the difference among the water stress under same level of nutrient rates and among the nutrient rates under same level of water stress.)

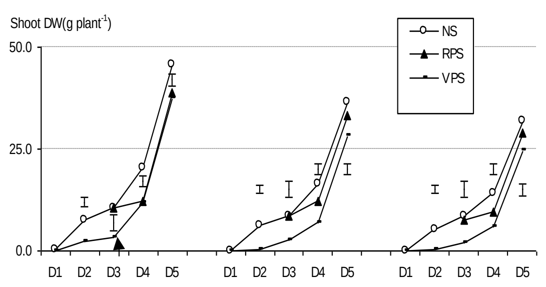

Fig. 3. Shoot dry weight as affected by nutrient rates and drought stress throughout the experimental period. Arrow at D3 indicates the end of the VPS and start of RPS. (Vertical bars represent the LSD (0.05) value indicates the difference among the water stress under same level of nutrient rates and among the nutrient rates under same level of water stress.)

Grains number and sterility percentage. Regardless of nutrient rates, RPS plants significantly ($P<0.05$) produced the lowest number of grains panicle^{-1} followed by VPS plants. The NS plants produced the highest number of grains panicle^{-1}. There was no significant difference between NS and VPS plants except OD. The RPS plants were in stressed condition in reproductive phase. As a result it produced the lowest number of grain panicle^{-1}. This result also supported the findings of Anonymous (1990), BRRI (1991), they reported that water stress decreased filled spikelet number, increased empty spikelet number and decreased grain yield.

Despite moisture stress, the highest number of grains panicle^{-1} was observed in OD followed by HD. The lowest number of grains panicle^{-1} was observed in F0. However, in RPS plants, there was no significant difference between OD and HD indicated that OD plants could not produced significantly more grain under moisture stress perhaps concentration of nutrients in the root zone increased so sharply that affected the distribution of nutrients as well as photosynthates from source to sink. As a result grains panicle^{-1} were not increased even after application of optimum doses (OD) of nutrients reflected in the higher percentage of sterility in OD of RPS plants.

Thousand grains weight. The 1000 grains weight (TGW) was not significantly ($P>0.05$) affected by drought stress, nutrient rates and their interaction, as it is a varietal character normally may not be affected by cultural practices (Yoshida, 1981). Moreover, water stress was not applied during grain filling period, hence 1000 grain weight was not affected.

Table 1. Yield and yield components of rice as affected by the interaction effect of drought stress and nutrient rates.

	Panicle no. (m^{-2})			Grains panicle^{-1}		
Treatment	NS	VPS	RPS	NS	VPS	RPS
F0	197 bA	189 bAB	183 bB	83 cA	79 cA	65 bB
HD	292 aA	223 aB	236 aB	90 bA	92 bA	78 aB
OD	301 aA	234 aB	241 aB	106 aA	99 aB	81 aC
LSD at 5%		12.4			4.3	

	% sterility			1000-grain weight (g)		
Treatment	NS	VPS	RPS	NS	VPS	RPS
F0	18 aC	23 aA	24 bA	22.19	22.02	21.76
HD	16 abC	21 abB	26 abA	22.38	22.23	22.34
OD	14 bC	19 bB	29 aA	22.26	22.13	21.85
LSD at 5%		3.1			ns	

	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})		
Treatment	NS	VPS	RPS	NS	VPS	RPS
FO	3.14 cA	2.73 bA	2.54 bA	5.30 bA	4.92 aA	5.14 bA
HD	5.62 bA	4.61 aB	4.30 aB	6.71 aA	5.20 aA	5.32 bA
OD	6.51 aA	4.50 aB	4.20 aB	7.23 aA	5.10 aC	6.70 aB
LSD at 5%		0.60			0.93	

In a column, numbers followed by different small letters (a, b, c) differ significantly at the 5% level by LSD test. In a row, numbers followed by different capital letters (A, B, C) differ significantly at the 5% level by LSD test.

Grain yield. Grain yield is a function of many factors like panicles m^{-2}, grains panicle^{-1} and (TGW) was also significantly ($P<0.05$) affected by the interaction effect of drought stress and nutrient rates. Regardless of nutrient rates, unstressed plants (NS) produced the highest grain yield (3.14 to 6.51 t ha^{-1}) followed by VPS (2.73 to 4.50 tha^{-1}) plants. The RPS plants produced the lowest grain yield (2.54 to 4.20 t ha^{-1}). This result supported the findings of Boonjung and Fukai (1996); Mostajeran and Rahimi-Eichi, (2009). They found that drought stress at vegetative phase of rice had a minor effect on subsequent growth and grain yield. But they observed that water stress at panicle development stage decrease grain yield due to delayed anthesis and the number of spikelets per panicle reduced upto 60% compared to control and the percentage of filled grains.

There was no significant difference among NS, VPS and RPS plants under F0. In HD and OD, there was no significant difference between VPS and RPS plant. Irrespective of water stress, OD produced the highest grain yield (4.20 to 6.51 t ha^{-1}) followed by HD (4.30 to 5.62 t ha^{-1}) and F0 (2.54 to 3.14 t ha^{-1}). There was no significant difference between HD and OD under VPS and RPS plants. Though OD produced the highest grain yield but due to water stress the highest grain yield reduction was observed in OD (22 –32%) followed by HD (12-19%) and the lowest in FO (4-15%) (Fig. 4).

Due to water stress the grain yield decreased more in plants grown in higher dose nutrient i.e. OD than HD and F0. This result confirms the findings of Power, 1990; Christianson and Vlek, 1991). They reported that with adequate amounts of soil moisture (humid=350 mm mid-season rainfall), grain yield of cereal response to nutrients is significant, but during severe drought (dry=100 mm mid-season rainfall) mineral application actually reduced yields. This result also supported the findings of Halder and Burrage (2007).

Straw yield. Irrespective of nutrient rates, unstressed plants (NS) produced the highest straw yield (5.30 to 7.23 t ha^{-1}) followed by RPS (5.14 to 6.70 t ha^{-1}) plants. The VPS plants produced the lowest straw yield (4.92 to 5.20 t ha^{-1}). There was no significant difference among NS, VPS and RPS except OD. Irrespective of water stress, the OD gave the highest straw yield (5.21 to 7.23 t ha^{-1}) followed by HD (5.20 to 6.71 t ha^{-1}) and F0 (4.92 to 5.30 t ha^{-1}) but there was no significant ($P>0.05$) difference between F0 and HD of RPS plants, between HD and OD treatments of NS plants and among F0, HD, OD of VPS plants. In this experiment water stress decreased tiller number and plant height hence decreased straw yield. This is an agreement with the findings of Hossain *et al.* 2002.

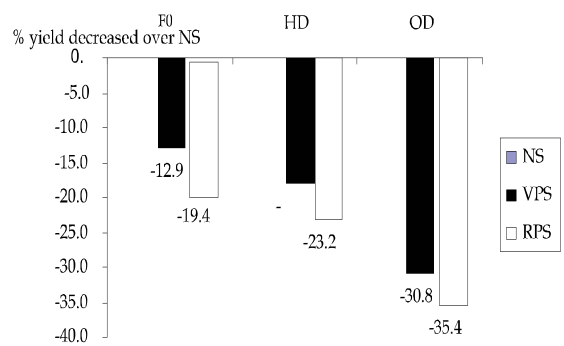

Fig. 4. Percent grain yield reduction in VPS and RPS plants over unstressed (NS) plants.

CONCLUSION

Water stress decreased growth of the plant due to reduction of plant height and tiller number. When a higher dose of fertilizer was applied in stressed plant, there was a greater percentage of reduction of grain yield than the lower dose of fertilizer applied stressed plant. Therefore, if fertilizer is applied, proper water supply must be ensured, otherwise yield will be reduced drastically.

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Assessment of Variability for Floral Characteristics and Out-Crossing Rate in CMS Lines of Hybrid Rice

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ABSTRACT

The present investigation was aimed to clarify the interrelationship among various floral traits and out crossing rates. High mean value, range of variability and genotypic variance were observed for all the traits except anther length and breadth, stigma length and breadth. Close differences between genotypic and phenotypic variances and genotypic and phenotypic coefficient of variations were observed for all the traits. Considering all genetic parameters, selection based on panicle exertion rate, angle of florate opening, duration of florate opening, anther length, stigma exertion rate and out crossing rate seemed to be effective for the improvement of CMS lines. Out crossing rate had significant positive correlation with panicle exertion rate, angle of florate opening, duration of florate opening, filament length, stigma length, breadth and exertion rate exhibited interesting results, indicating selection with these traits might be possible without compromising seed yield loss. On the basis of direct selection through panicle exertion rate, angle and duration of florate opening, filament length and stigma exertion rate would significantly improve seed yield of CMS lines. Based on mean, range, genetic parameters, correlation coefficient and path coefficient values, direct selection of eight CMS lines IR79156A, BRRI7A, IR75608A, BRRI13A, BRRI35A, BRRI48A, BRRI50A and BRRI53A might be fruitful as good floral characteristics with high out crossing rate of CMS lines.

Key words: Variability, heritability, correlation coefficient, stigma exertion rate

INTRODUCTION

Rice is a major source of livelihood in terms of providing food, income and employment in Bangladesh. It covers about 77 percent of the total cropped area in the country. Rice production in Bangladesh remains almost stagnant in the 2016 at around 34.18 MMT (rough rice or paddy) from 11.6 million hectares of land (Wallace, 2017). But the population growth rate accelerated, so this burgeoning population needs more food. Rice breeder have therefore, been trying to evolve input-efficient high yielding varieties (HYV) to increase the yield through limited land, labour, water etc. One innovation has been the development of hybrid rice varieties for the tropics, which is expected to shift the yield potential of rice plant by 15-20 percent or more. The technology has attracted the attention of research leaders and policy-makers in many Asian countries who see it as an opportunity to overcome the yield ceilings. The discovery of CMS in rice suggested that breeding could develop a commercially viable F_1 hybrid (Athwal and Virmani, 1972). The most promising hybrids yielded 20-30% (Lin and Yuan, 1980) and l5-20% (Yuan, 1998) higher than the best conventional rice varieties. Therefore, to break through the present yield ceiling of semi dwarf modern varieties, hybrid rice seems to be an attractive viable alternative. It is urgently needed to develop parental lines viz. A lines, B lines and R lines for developing hybrid rice varieties, with resistance to disease or environmental

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changes this situation could be reduced by developing CMS lines having diverse cytoplasmic source with stable male sterility, high out crossing rate, good resistance to diseases and other stresses. A plant breeding programme can be divided into three stages, viz. building up a gene pool of variable germplasm, selection of individuals from the gene pool and utilization of selected individuals to evolve a superior variety (Kempthorne, 1957). The available variability in a population can be partitioned into heritable and non heritable parts with the aid of genetic parameters such as genetic coefficient of variation, heritability and genetic advance (Miller *et al.*, 1958). Correlation coefficient helps to identify the relative contribution of component characters towards yield (Panse, 1957). The correlation between yield and a component character may sometimes be misleading. Thus splitting of total correlation into direct and indirect effects would provide a more meaningful interpretation of such association.

Path coefficient, usually a standard partial regression coefficient, specifies the cause and effect relationship and measures the relative importance of each variable. Therefore, correlation in combination with path coefficient analysis will be an important tool to find out the association and quantify the direct and indirect influence of one character upon another (Dewey and Lu, 1959). Improvement of out crossing rate of CMS lines with high panicle exertion rate and stigma exertion rate through the knowledge of variability, association among various floral traits along with direct and indirect influence of these component traits on seed yield has so far been lacking. Therefore, objectives of the present study were to i) analyze variability in genetic parameters, association among different floral traits on out crossing rate of 30 promising CMS lines available in Bangladesh; ii) determine contribution of the component traits towards seed yield potential; and finally iii) find out appropriate selection parameters for the improvement of CMS lines.

MATERIALS AND METHODS

Thirty CMS lines, some developed by BRRI and some collected from IRRI were grown in November 2015, consecutively in a randomized complete block design (RCBD) with three replications in BRRI experimental fields, Gazipur. Thirty-day-old seedlings were transplanted in 4.6 m^2 areas using single seedling per hill. Fertilizer doses were 80: 60: 40 kg N P K and 70 kg gypsum per hectare. Except N all other fertilizers were used as basal dose and N fertilizer was top dressed in three equal splits at 15, 30 and 45 days after transplanting. Standard crop management practice was done as and when necessary. Data were collected at flowering time of ten randomly selected plants were considered from each replication for measuring panicle exertion rate (PER), angle of floret opening (AFO), duration of floret opening (DFO), filament length (FL), anther length (AL), and breadth (AB), stigma length (SL), breadth (SB), exertion rate (SER) and out crossing rate (OCR).

The raw data were compiled by taking the means of all the plants taken for each treatment and replication for different traits. The mean data were averaged and the average mean values were statistically analyzed. Analysis of variance was done according to Panse and Sukhatme (1978) for each character. Genotypic and phenotypic variances, phenotypic (PCV) and genotypic coefficient of variation (GCV), heritability in broad sense (h^2b) and expected genetic advance (GA %) were estimated according to Johnson et al. (1955a). Correlation coefficient was analyzed following Hayes *et al.* (1955). Path coefficient analysis was calculated according to the formula given by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences among the genotypes for all the ten traits, which was the indication of the validity of further statistical analysis due to the presence of a wide range of variability among the 30 CMS lines. Mean performance, % CV and CD for floral character and out crossing rate in 30 CMS lines (Table 1).

Floral traits

Panicle exertion rate. Among the 10 traits investigated, the highest panicle exertion rate was observed in IR79156A (78.26%) followed by BRRI7A (77.44%) and IR75608A (75.59%). Rajkumar and Ibrahim (2015) reported that the highest panicle exertion rate was recorded in CMS line IR58025A and the lowest was in IR79156A. The mean panicle exertion rate was 64% and 0.56% coefficient of variation.

Table 1. Mean performance, coefficient of variation (CV) and critical difference (CD) values of floral attributes of 30 CMS lines.

CMS lines	PER	AFO	DFO	FL	AL	AB	SL	SB	SER	OCR
BRRI10A	58.43	20.57	130.9	5.50	1.57	0.46	1.22	0.35	55.31	22.38
BRRI11A	58.35	20.40	128.8	5.43	1.53	0.45	1.22	0.31	54.75	21.99
GuiA	56.43	20.14	125.1	5.33	1.47	0.44	1.21	0.29	54.22	21.60
BRRI28A	54.92	20.13	122.9	5.27	1.52	0.44	1.20	0.29	51.36	20.70
BRRI30A	54.93	19.68	115.8	5.17	1.45	0.43	1.10	0.28	50.97	20.33
BRRI32A	54.69	19.30	111.8	5.07	1.41	0.43	1.09	0.27	48.84	20.01
You1A	54.52	19.10	106.6	4.97	1.36	0.38	0.95	0.27	48.44	18.46
BRRI4A	53.91	18.83	97.45	4.77	1.08	0.41	0.98	0.23	48.18	18.14
BRRI6A	53.31	18.03	87.42	4.53	1.14	0.40	0.97	0.25	46.21	16.89
BRRI8A	52.45	17.71	79.13	4.67	1.21	0.43	1.08	0.26	46.78	15.37
IR79156A	78.26	26.11	182.8	6.77	2.47	0.55	1.52	0.58	79.28	35.78
D ShanA	62.16	21.06	137.6	5.70	1.67	0.48	1.30	0.40	58.14	23.19
IR58025A	60.00	20.86	136.3	5.63	1.63	0.48	1.28	0.40	55.84	22.81
BRRI1A	59.33	20.64	131.7	5.57	1.60	0.47	1.26	0.38	55.59	22.54
BRRI7A	77.44	25.38	185.3	6.80	2.77	0.58	1.66	0.58	80.31	35.41
BRRI50A	72.19	23.86	169.8	6.37	2.30	0.54	1.51	0.56	72.63	30.68
BRRI53A	70.54	23.49	165.7	6.33	2.23	0.53	1.50	0.56	72.20	30.28
BRRI72A	70.18	23.34	164.2	6.30	2.17	0.52	1.49	0.55	68.69	29.98
IR68886A	69.51	23.03	163.6	6.27	2.10	0.52	1.45	0.55	68.23	28.31
IR68888A	69.13	22.77	160.5	6.20	2.07	0.52	1.45	0.54	67.58	27.85
IR68897A	67.12	22.45	159.2	6.19	2.03	0.51	1.44	0.54	64.69	25.79
II32A	66.46	22.13	157.6	6.17	2.00	0.51	1.44	0.53	64.16	25.49
Jin23A	65.46	21.66	152.6	6.10	1.87	0.51	1.34	0.42	61.76	25.20
V20A	63.54	21.50	149.2	5.99	1.80	0.50	1.33	0.42	61.24	24.99
IR75608A	75.59	24.53	178.8	7.27	2.60	0.57	1.65	0.61	78.91	33.76
BRRI13A	74.47	24.14	176.7	6.63	2.87	0.56	1.62	0.57	76.57	33.35
BRRI35A	74.19	24.19	176.0	6.53	2.40	0.58	1.53	0.57	75.87	32.65
BRRI48A	73.58	23.95	173.7	6.47	2.33	0.54	1.67	0.56	74.63	32.35
2597A	63.31	21.38	144.7	5.93	1.73	0.49	1.33	0.42	59.23	23.78
Gan46A	62.51	21.12	142.0	5.77	1.70	0.48	1.32	0.41	58.23	23.46
Mean	64.23	21.72	143.79	5.86	1.87	0.49	1.34	0.43	61.96	25.45
CV(%)	0.56	1.40	0.34	2.36	4.06	1.98	3.76	2.48	0.42	0.94
CD	0.599	0.509	0.811	0.230	0.129	0.053	0.091	0.052	0.439	0.399

Legend: PER = Panicle exertion rate (%), AFO = Angle of florat opening (0°), DFO = Duration of florate opening (min), FL = Filament length (mm), AL = Anther length (mm), AB = Anther breadth (mm), SL = Stigma length (mm), SB = Stigma breadth (mm), SER = Stigma exertion rate (%) and OCR = Out crossing rate (%).

Angle of floret opening. This trait varied from 17.71° (BRRI8A) to 26.11° (IR79156A) with a mean value 21.72°. Vagolu (2010) also observed mean value of CMS line was 22.90°. The coefficient of variation for this trait was 1.40%.

Duration of floret opening. The variation for this character ranged from 79.13 to 185.3 minute with a mean value 143.79 minute. BRRI7A and IR79156A also recorded higher duration of floret opening.

Filament length. The trait filament length was varied from 4.53 mm (BRRI6A) to 7.27 mm (IR75608A) with an overall mean value of 5.86mm. The highest filament length was observed in the CMS line IR75608A followed by CMS line BRRI7A (6.80 mm) and IR79156A (6.77 mm). Among 30 CMS lines studied 16 CMS lines had higher filament length than the mean value. The coefficient of variability was 2.36% for filament length.

Anther length. The variations of the anther length were highly pronounced among the CMS lines which ranged from 1.08 mm in the CMS line BRRI4A to 2.87 mm in the CMS line BRRI13A. The average mean of the anther length was 1.87 mm, 13 CMS line showed above average performance for anther length. The coefficient of variation for this trait was 4.06%.

Anther breadth. The anther breadth among the CMS lines studied ranged from 0.38 mm (You1A) to 0.58 mm (BRRI35A) with a mean value of 0.49 mm. The CMS lines BRRI35A and BRRI7A also recorded higher anther breadth. The coefficient of variation was 1.98.

Stigma length. The trait varied from o.95 mm (You1A) to 1.67 mm (BRRI48A) with mean value of 1.34 mm. Among the 30 CMS lines BRRI48A and BRRI7A recorded higher stigma length. Vagolu (2010) also assessed the similar result in CMS lines. The coefficient of variation was 1.34.

Stigma breath. Although the stigma breadth had significant variations among the CMS lines, the range of variations of the lines weren't pronounced (0.23 mm to 0.61 mm). The highest stigma breadth was found in IR75608A followed by BRRI7A (0.58 mm) and IR79156A (0.58 mm). The coefficient of variation for this trait was 2.48.

Stigma exsertion rate. The variations of the stigma exertion rate were highly pronounced among the genotypes which ranged from 46.21% in the CMS lines BRRI6A to 80.31% in the CMS lines BRRI7A. The average mean of the stigma exertion rate was 61.96%. Thirteen CMS lines showed above average performance for stigma exertion rate, of which 6 CMS lines viz BRRI7A, IR79156A, IR75608A, BRRI13A, BRRI35A and BRRI48A showed outstanding stigma exertion rate 80.31%, 79.28%, 78.91%, 76.57%, 75.87% and 74.63% respectively. The CV for this trait was 0.42%.

Out crossing rate. Enormous out crossing rate was obtained from 30 CMS lines investigated that ranged from 15.37% (BRRI8A) to 35.78% (IR79156A) with an average value of 25.45%. The highest OCR was obtaining from the CMS line IR79156A, followed by CMS lines BRRI7A (35.41%), IR75608A (33.76%), BRRI13A (33.35%), BRRI35A (32.65%) and BRRI48A (32.35%). Out of 30 CMS lines studied eight had OCR>30% while four CMS lines (BRRI8A, BRRI6A, BRRI4A and You1A) had lower OCR. From this investigation it was revealed that when out crossing rates high it is associated with high rates in other floral traits. The investigation also showed that eight CMS lines IR79156A, BRRI7A, IR75608A, BRRI13A, BRRI35A, BRRI48A, BRRI50A and BRRI53A were out yielded over their corresponding means.

Variability studies

Variability plays a vital role in the selection of superior genotypes in crop improvement programme. Pronounced variation in the breeding materials is a prerequisite for development of varieties to fulfill the existing demand. Economically important traits are generally quantitative in nature that interacts with the environment where it is grown. This is why breeder should calculate the variability by partitioning into genotypic, phenotypic, and environmental effects. Creation of variability is prerequisite for crop breeders. Floral traits are quantitative in nature, and interact with the environment under study, so partitioning the traits into genotypic, phenotypic, and environmental effects is essential to find out the additive or heritable portion of variability. Table 2 presents the mean, range, genotypic and phenotypic variance (V_g, V_p) and coefficient of variation (GCV, PCV), h^2b, GA and GA in percent of mean. In the present investigation, the range of variation was much prominent for all the traits except anther breadth and stigma breadth indicating a wide range of variability among the CMS lines studied. High genotypic and phenotypic variances were observed for panicle exertion rate, angle of floret opening, duration of florate opening, filament length, stigma exertion rate and out crossing rate showing the presence of the wide range of variability among the traits in CMS lines. In contrast anther length, anther breadth, stigma length and breadth had showed low genotypic and phenotypic variances that indicate no scope of selection on the basis of these traits for improvement of CMS lines. Panicle exertion rate, angle of florate opening, duration of florate opening, filament length, stigma exertion rate and out crossing rate had close differences in genotypic and phenotypic variances along with genotypic coefficient of variability (GCV) and phenotypic coefficient of variability (PCV) values, indicating preponderance of additive gene effects for these traits. Less environmental influence in the expression of these traits or the major portion of the phenotypic variance was genetic in nature and greater scope of improvement of CMS line through selection. Hossain *et al.* (2016) reported similar findings. Variability alone is not of much help in determining the heritable portion of variation. The amount of gain expected from a selection depends on heritability and genetic advance in a trait.

Heritability has been widely used to assess the degree to which a character may be transmitted from parent to offspring. Knowledge of heritability of a character is important as it indicates the possibility and extent to which improvement is possible through selection. However, high heritability alone is not enough to make sufficient improvement through selection generally in advance generations unless accompanied by a substantial amount of genetic advance (Johnson *et al.*, 1955b). The expected genetic advance is a function of selection intensity, phenotypic variance, and heritability and measures the differences between the mean genotypic values of the original population from which the progeny is selected. It has been emphasized that genetic gain should be considered along with heritability in coherent selection breeding programme (Sarker *et al.*, 2015). It is considered that if a trait is governed by non-additive gene action it may give high heritability but low genetic advance, which limits the scope for improvement through selection, whereas if it is governed by additive gene action, heritability and genetic advance would be high, consequently substantial gain can be achieved through selection. The heritability was high for all the traits indicated the preponderance of additive gene action for these traits. High heritability coupled with high GA in percent of mean was observed for all the traits indicated that were governed to a great extent by additive gene. So selection based on these traits would be effective for the improvement of CMS lines. High heritability (84.9) and high genetic advance as percent of mean (23.54) were recorded for stigma exertion rate by Vagolu (2010).

Table 2. Genetic parameter for floral attributes of 30 CMS lines.

Character	Range	MS	σ^2g	σ^2e	σ^2p	GCV	PCV	h^2_b	GA	GAPM
PER	52.45-78.26	196.53**	65.47	0.13	65.60	12.60	12.67	99.80	12.77	19.88
AFO	17.71-26.11	14.19**	4.70	0.09	4.79	9.98	10.08	98.06	3.39	15.62
DFO	79.13-185.3	2522.59**	840.79	0.23	841.02	20.16	20.17	99.97	45.81	31.86
FL	4.53-7.27	1.42**	0.47	0.02	0.49	11.68	11.91	96.10	1.06	18.09
AL	1.08-2.87	0.69**	0.23	0.01	0.24	25.57	25.90	97.44	0.75	39.87
AB	0.38-0.58	0.009**	0.01	0.01	0.02	10.52	12.33	72.73	0.07	14.17
SL	0.95-1.67	0.13**	0.04	0.01	0.05	15.44	15.97	93.43	0.32	23.58
SB	0.23-0.61	0.05**	0.02	0.01	0.03	29.21	30.11	94.12	0.19	44.78
SER	46.21-80.31	348.22**	116.05	0.07	116.12	17.39	17.39	99.94	17.02	27.46
OCR	15.37-35.78	97.41**	32.45	0.06	32.51	22.38	22.40	99.82	8.99	35.33

** = Significant at the 1% level, σ^2g = Genotypic variance, σ^2e = Environmental variance, σ^2p = Phenotypic variance, GCV = Genotypic coefficients of variations, PCV = Phenotypic coefficients of variations, h^2_b = Heritability in broad sense, GA = Genetic advance, GAPM = Genetic advance percent of mean. PER = Panicle exertion rate(%), AFO = Angle of florat opening (0°), DFO = Duration of florate opening (min), FL = Filament length (mm), AL = Anther length (mm), AB = Anther breadth (mm), SL = Stigma length (mm), SB = Stigma breadth (mm), SER = Stigma exertion rate (%) and OCR = Out crossing rate (%).

Correlation studies

Table 3 presents the phenotypic and genotypic correlations between the various characters. In the present investigation, the genotypic correlation coefficients were very much close to the corresponding phenotypic values for all the traits indicating additive type of gene action i.e., less environmental influence on the expression of the traits.

From Table 3 it was revealed that out crossing rate had a significant positive correlation with panicle exertion rate (0.986**), angle of florate opening (0.895**), duration of florate opening (0.865**), filament length (0.777**), stigma length (0.884**), stigma breadth (0.746**) and stigma exertion rate (o.993**) indicating selection for high panicle exertion rate, angle of florate opening, duration of florate opening, filament length, stigma length, breadth and exertion rate were closely

Table 3. Genotypic (r_g) and phenotypic (r_p) correlation coefficient for floral attributes of 30 CMS lines.

Character		AFO	DFO	FL	AL	AB	SL	SB	SER	OCR
PER	r_g	0.989**	0.964**	0.883**	0.392	0.567	0.785**	0.777**	0.995**	0.986**
	r_p	0.981**	0.963**	0.768**	0.331	0.429	0.765**	0.674*	0.894**	0.884**
AFO	r_g		0.881**	0.898**	0.473	0.596	0.791**	0.863**	0.791**	0.895**
	r_p		0.875**	0.817**	0.442	0.379	0.779**	0.756**	0.684*	0.788**
DFO	r_g			0.628	0.565	0.494	0.698*	0.763**	0.963**	0.865**
	r_p			0.553	0.491	0.435	0.478	0.660*	0.862**	0.764**
FL	r_g				0.629*	0.684*	0.564	0.473	0.778**	0.777**
	r_p				0.587	0.632*	0.504	0.351	0.664*	0.665*
AL	r_g					0.592	0.434	0.454	0.593	0.696
	r_p					0.521	0.364	0.444	0.484	0.646
AB	r_g						0.255	0.372	0.685	0.685
	r_p						0.198	0.259	0.475	0.574
SL	r_g							0.774**	0.784**	0.884**
	r_p							0.650*	0.767**	0.823**
SB	r_g								0.764**	0.746*
	r_p								0.662*	0.643*
SER	r_g									0.993**
	r_p									0.892**

** = Significant at the 1% level and * = Significant at the 5% level, PER = Panicle exsertion rate (%), AFO = Angle of florat opening (0°), DFO = Duration of florate opening (min), FL = Filament length (mm), AL = Anther length (mm), AB = Anther breadth (mm), SL = Stigma length (mm), SB = Stigma breadth (mm), SER = Stigma exsertion rate (%) and OCR = Out crossing rate(%).

associated with high out crossing rate i.e. increase in panicle exertion rate, angle of florate opening, duration of florate opening, filament length, stigma length, breadth and exertion rate could lead to increase the out crossing rate of CMS line. Rajkumar and Ibrahim (2015) revealed that panicle exertion rate had positive association with out-crossing rate. Similarly Roy *et al.* (2015) observed significant positive association between yield and its contributing traits in rice. Stigma exertion rate had the significant positive association with panicle exertion rate (0.995**), angle of florate opening (0.791**), duration of florate opening (0.963**), filament length (0.778**), stigma length (0.784**) and stigma breadth (0.764**) indicating high stigma exertion rate with high out crossing rate. A similar trend was observed by earlier work in CMS line (Hossain *et al.*, 2016). Genotypic correlation was found insignificant between stigma breadth with anther length and breadth. It was also found insignificant between stigma length with anther length and breadth indicated that selection for high anther length and breadth might be possible without compromising seed yield loss. Similarly, no significant association was found between anther breadth and length with panicle exertion rate, angle of florate opening, duration of florate opening. Filament length and duration of florate opening showed significant positive association with panicle exertion rate and angle of florate opening that exhibited a significant positive correlation with panicle exertion rate.

Path coefficient studies

Path coefficient analysis was carried out using genotypic correlation coefficient among ten floral traits to estimate the direct and indirect effect on out crossing rate in CMS line (Table 4). The angle of florate opening (0.821) and stigma exertion rate (0.771) exhibited high positive direct effect on out crossing rate. On the other hand, high negative direct effect was observed in stigma length (-0.407) and moderate negative direct effect was found in anther length (-0.244) and stigma breadth (-0.247). Anther breadth (=0.002) had negligible negative direct effect on out crossing rate. Similarly, Hasan *et al.*, (2015) observed that yield contributing traits had direct positive effect on grain yield in hybrid rice. Hossain *et al.*, (2016) also observed percent stigma exertion had remarkable positive direct effect on out crossing rate. The panicle exertion rate (0.123) showed little positive direct effect on out crossing rate. The duration of florate opening (0.103) and filament length (0.198) exhibited considerable positive direct effect on out crossing rate. It was interesting that path coefficient analysis results confirmed the similarity of the correlation coefficient analysis result. Anther length had considerable negative direct effect and insignificant positive correlation and anther breadth exhibited negligible negative direct effect and insignificant positive correlation. Direct selection based on these two traits (anther length and breadth) would not be effective for the improvement of out crossing rate i.e. seed yield of CMS lines. Concomitant selection based on high panicle exertion rate and high out crossing rate would be effective for the improvement of CMS lines. Panicle exertion rate showed considerable positive direct effect with high positive genotypic correlation on out crossing rate. Vagolu (2010) revealed that panicle exertion rate had positive direct effect and positive correlation with out-crossing percentage. Direct selection on the basis of panicle exertion rate would be effective for improving out crossing rate as well as seed yield of CMS lines.

Large amount of variability in respect of panicle exertion rate, floral characteristics and stigma exertion rate were observed among the CMS lines while analyzing genetic parameters, correlation and path coefficient values and interpretation of these results. Breeder may utilize the present findings for developing

Table 4. Partitioning of genotypic correlation into direct (bold) and indirect effect for floral attributes of 30 CMS lines.

Character	Effect through									OCR
	PER	AFO	DFO	FL	AL	AB	SL	SB	SER	
PER	**0.123**	0.812	0.099	0.194	-0.241	-0.003	-0.400	-0.240	0.766	0.986**
AFO	0.002	**0.821**	0.101	0.197	-0.244	-0.002	-0.403	-0.237	0.763	0.895**
DFO	0.002	0.806	**0.103**	0.196	-0.235	-0.001	-0.406	-0.237	0.741	0.865**
FL	0.002	0.820	0.103	**0.198**	-0.241	-0.001	-0.412	-0.239	0.754	0.777**
AL	0.002	0.821	0.099	0.196	**-0.244**	-0.002	-0.403	-0.235	0.764	0.696
AB	0.003	0.817	0.102	0.200	-0.242	**-0.002**	-0.408	-0.239	0.759	0.685
SL	0.002	0.813	0.103	0.200	0.241	-0.001	**-0.407**	-0.240	0.759	0.884**
SB	0.002	0.790	0.099	0.192	-0.232	-0.001	-0.396	**-0.247**	0.743	0.746*
SER	0.002	0.813	0.099	0.193	-0242	-0.002	-0.400	-0.238	**0.771**	0.993**

Residual effect – 0.067. ** = Significant at the 1% level and * = Significant at the 5% level. PER = Panicle exertion rate(%), AFO = Angle of florate opening (0°), DFO = Duration of florate opening (min), FL = Filament length (mm), AL = Anther length (mm), AB = Anther breadth (mm), SL = Stigma length (mm), SB = Stigma breadth (mm), SER = Stigma exsertion rate (%) and OCR = Out crossing rate (%).

high seed producing CMS line with good floral characteristics in future. Further investigation may be carried out to confirm the study in different locations of Bangladesh for their stability analysis.

CONCLUSION

Considering high genotypic and phenotypic variance along with genotypic coefficient of variability and phenotypic coefficient of variability values, high heritability coupled with high genetic advance and genetic advance in percent of mean of six traits i.e. panicle exertion rate, angle of florate opening, duration of florate opening, anther length, stigma exertion rate and out crossing rate would be selected for the improvement of 30 CMS lines under study. However, correlation study revealed that strong positive association of panicle exertion rate, angle of florate opening, duration of florate opening, filament length, stigma length, breadth and exertion rate with out-crossing rate. Selection based on panicle exertion rate, angle of florate opening, duration of florate opening, filament length, stigma length, breadth and exertion rate could lead to increase the seed yield of CMS line. Based on direct selection through panicle exertion rate, angle of florate opening, duration of florate opening, filament length and stigma exertion rate would significantly improve seed yield of CMS lines. On the basis of mean, genetic parameters, correlation coefficient value and direct selection of eight CMS lines IR79156A, BRRI7A, IR75608A, BRRI13A, BRRI35A, BRRI48A, BRRI50A and BRRI53A might be selected as good floral characteristics with high out-crossing rate of CMS lines.

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Agro-morphological Characterization of Bangladeshi Aromatic Rice (*Oryza sativa* L.) Germplasm Based on Qualitative Traits

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ABSTRACT

The agro-morphological characterization of germplasm is of utmost importance to generate information to be utilized in plant breeding programmes. The aim of this study was to characterize the agro-morphological traits of 113 accessions of aromatic germplasm (*Oryza sativa* L.) based on qualitative agro-morphological descriptors. No duplicates were identified among the studied accessions for qualitative traits in the cluster analysis, which means there is a high diversity among the accessions for these traits. Following UPGMA cluster analysis, 113 accessions of aromatic germplasm formed ten distinct clusters. The highest numbers of germplasm (96) were found in cluster IXd, 2 were found in cluster III, IV and VI, 3 were found in IXc and the lowest number of germplasm (1) in cluster I, II,V, VII, VIII, IXa, IXb and X, respectively. Aroma evaluation revealed that 67 germplasm were scented, 34 were lightly scented, while the rest 12 germplasm were non-scented. Germplasm namely Begun bichi, Elai, Chinigura, Basmati 370, Ranisalut, Sakkorkhora, Jirakatari, Raduni Pagal, Kalijira (long grain), Black TAPL-554, Kalgochi, BRRI dhan34, BRRI dhan50, Badshabhog-2, Tulsimala-2, Kataribhog, BU dhan2R , Sakkorkhana, Maloti, Bashful could be used for further improvement for incorporating aroma to the high yielding varieties.

Keywords: Agro-morphological characterization, aromatic rice germplasm, qualitative traits

INTRODUCTION

Bangladesh is mainly a country of rice based cropping system, where thousands of local rice varieties are being cultivated from the time immemorial. Still now, farmers are cultivating local landraces in most of the unfavourable ecosystems. Traditional varieties have some special characteristics such as aroma, taste and better cooking quality, which also provide additional value in socio-economic aspects. Moreover, aromatic rice germplasm constitutes a special group of rice genotypes well known in many countries of the world for their aroma and or super fine grain quality (Singh *et al*., 2000, Islam *et al*., 2013). The Himalayan foothills including parts of Bangladesh are considered to be the secondary centre of diversity of the genus *oryza* (Morishima, 1984). Bangladesh has a stock of above 8,500 rice germplasm of which around 100 are aromatic genotypes (Islam *et al*., 2018a). The Bangladeshi aromatic and fine rice germplasm is comprised of short and medium bold types with mild to strong aroma (Shahidullah *et al*., 2009; Islam *et al*., 2016). Since the time of civilization, thousands of locally adapted aromatic rice genotypes have evolved as a consequence of natural and human selection. These landraces are the genetic reservoirs of useful genes. The large scale spread of modern, high yielding varieties have replaced the traditional varieties especially in the irrigated rice ecosystem leading to reduced genetic base and thus increased genetic vulnerability. Therefore, rice germplasm need

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to be utilized for maintaining its diversity in the field.

Agro-morphological characterization of germplasm accessions is essential in order to offer information for plant breeding programmes (Nascimento *et al.,* 2011). Several researchers reported the use of agro-morphological markers in the characterization and study of rice (*Oryza sativa* L.) germplasm diversity (Islam *et al.*, 2017; Mau *et al.*, 2017; Akter *et al.*, 2018). Aromatic rice varieties in general are tall statured, possess fewer number of panicles, high stem weight, lower yields and susceptible in lodging (Islam *et al.*, 2016). Glaszmann (1987) reported that aromatic rice germplasm fall into a separate group from that of the typical indicas and declared that these two groups are incompatible causing inter-group hybrid sterility. Recently it is revealed that 2-acetyl-1-pyrroline based fragrance in rice is due to the presence of a non-functional betaine aldehyde dehydrogenase 2 (BADH2) (Bradbury *et al.*, 2005, 2008). The non-functional BADH2 interferes in pollen tube development and this could be the cause for the low grain yield in aromatic germplasm (Bradbury *et al.*, 2008). Morphological characterization is the first step in the classification and assessment of the germplasm. Although large number of germplasm collections is known to exist in BRRI Genebank in Bangladesh, not all of them have been fully and properly characterized and documented. Therefore, systematic attempts have to be taken to make a total inventory of this valuable gene pool for quantifying the availability of new useful genes of this source. Besides, it is very important to protect bio-piracy and geographical indications and issues related Intellectual Property Rights (IPR). On the other hand, researches on qualitative traits evaluation on aromatic rice germplasm are almost nil. Considering the above fact, the present study was initiated to characterize the qualitative agro-morphological characters of aromatic germplasm of Bangladesh.

MATERIALS AND METHODS

Experimental site and plant materials

The experiment was conducted at the farm of Bangladesh Rice Research Institute (BRRI), Gazipur in T. Aman season, 2011. A total of 113 aromatic germplasm were evaluated using "Germplasm Descriptors and Evaluation Form" approved by BRRI (Table 1). Names for the 113 aromatic rice germplasm along with methods have been previously described by Islam *et al*. (2016).

Agro-morphological traits observation

We observed variables of 28 qualitative agro-morphological characters namely: 1. Blade pubescence, 2. Blade colour, 3. Leaf sheath: anthocyanin colour (early to late vegetative stage), 4. Basal leaf sheath colour (early to late vegetative stage), 5. Leaf angle (prior to heading), 6. Flag leaf angle (after heading), 7. Ligule colour (late vegetative stage), 8. Ligule shape (late vegetative stage), 9. Coller colour (late vegetative stage), 10. Auricle colour (late vegetative stage), 11. Culm: anthocyanin colouration of nodes (after flowerting), 12. Culm angle (after flowerting), 13. Internode colour (after flowering), 14. Culm strength (after flowerting to maturity), 15. Panicle type (near maturity), 16. Secondery branching (near maturity), 17. Panicle exsertion (near maturity), 18. Spikelet: awns in the spiklet, 19. Spikelet: length of the longest awn (flowering to maturity), 20. Distribution of awning (flowering to maturity), 21. Awn colour (at maturity), 22. Apiculus colour (at maturity), 23. Stigma colour (at flowering), 24. Lemma and palea colour (at maturity), 25. Lemma and palea pubescence (at maturity), 26. Seed coat colour (at maturity), 27. Leaf senescence (at maturity), 28. Decorticated grain: scent (aroma), at maturity stage. The observed qualitative traits were scored based on "Germplasm Descriptors and Evaluation Form" issued by BRRI prior to data analysis (Table 2).

Table 1. List of 113 aromatic germplasm used in morphological characterization.

Germplasm	Acc. No.	District/Source	Germplasm	Acc. No.	District/Source
Sakor	197	Mymensingh	Khasa	682	Cumilla
Sagardana	229	Mymensingh	Buchi	369	Gaibandha
Nunia	233	Mymensingh	Awned TAPL-545	2939	GRSD, BRRI
Chini Sagar (2)	245	Mymensingh	Black TAPL-554	2947	GRSD, BRRI
Meny	288	Gaibandha	Straw TAPL-500	2898	GRSD, BRRI
Tilkapur	296	Gaibandha	Dubsail	4840	Satkhira
Binnaphul	315	Gaibandha	Duksail	2028	Satkhira
Kalobhog	318	Gaibandha	Khaskani	4341	Jashore
Jabsiri	331	Gaibandha	Khazar	4921	Iran
Kalgochi	352	Gaibandha	Basmati sufaid106	4498	Pakistan
Chinisakkor	387	Rajshahi	BR5	4343	GRSD, BRRI
Chiniatob	399	Rajshahi	BRRI dhan34	7093	GRSD, BRRI
Noyonmoni	461	Rajshahi	BRRI dhan37	7094	GRSD, BRRI
Saubail	873	Sylhet	BRRI dhan38	7095	GRSD, BRRI
Chinniguri	1880	Kishoreganj	BRRI dhan50	6882	GRSD, BRRI
Kalomala	1886	Kishoreganj	Khasa Mukpura	7586	Khagrachhari
Begunmala	1896	Kishoreganj	Uknimodhu	298	Gaibandha
Gopalbhog	1938	Kishoreganj	Bawaibhog-2	301	Gaibandha
Tulsimoni	1980	Jamalpur	Chiniatob-2	398	Rajshahi
Jirabuti	1984	Mymensingh	Tilokkachari	758	Chittagong
Khirshabuti	1996	Tangail	Begunbichi-2	508	Rangpur
Rajbut	1999	Tangail	Chinairri	764	Chottagram
Soru kamina	2015	Satkhira	Bhatir chikon	774	Chittagong
Kamini soru	2027	Satkhira	Gordoi	1908	Kishoreganj
Doiarguru	2037	Khulna	Dolagocha	451	Rajshahi
Premful	2041	Satkhira	Kalonunia	537	Rangpur
Begun bichi	2073	Kishoreganj	Dhan chikon	538	Dinajpur
Elai	2423	Dhaka	Badshabhog-2	03	Dhaka
Gua masuri	3666	Sherpur	Thakurbhog-2	872	Sylhet
Luina	3676	Netrokona	Khuti chikon	4107	Cumilla
Lal Soru	4135	Dinajpur	Sunduri samba	4803	Rajshahi
Chini Kanai	4356	Khulna	Basmati	4754	Barguna
Kalijira (short grain)	4357	Khulna	Basmati 37	4491	India
Rajbhog	4360	Khulna	Basnatu sufaid 187	4499	Pakistan
Philliphine kataribhog	4365	Dinajpur	Tulsimala-2	7342	Sherpur
Baoibhog	4813	Kurigram	Chinisail	7343	Sherpur
Baoijhaki	4826	Dinajpur	Malshira	7347	Sherpur
Jirabhog(Bolder)	4828	Dinajpur	Sadagura	-	Khagrachhari
Chinigura	4867	Mymensingh	Modhumadab	7352	Habigang
Tulsimala	4870	Mymensingh	Parbatjira	7351	Habigang
Bashmati 370	4904	Pakistan	Chinikanai-2	7350	Dinajpur
Uknimodhu	5083	Rangpur	Meedhan	7537	Habiganj
Ranisalut	5286	Khulna	Gobindhabhog	-	Jessore
Jira dhan	5313	Khulna	Kataribhog	7082	Dinajpur
Gandhakusturi	5319	Bagerhat	Fulkari	7531	Habiganj
Sakkorkhora	5347	Barguna	BU Dhan2R	7413	GRSD, BRRI
Badshabhog	5349	Bagerhat	Padmabhog	4812	Kurigram
Jirakatari	5975	Dinajpur	Dudsail	4840	Satkhira
Desikatari	5978	Dinajpur	Sakkorkhana	4761	Barguna
Thakurbhog	5983	Sylhet	Maloti	169	Tangail
Tulsimaloty	6638	Tangail	Bashful	4215	Kishoreganj
Raduni pagal	6711	Rajshahi	KalijiraTAPL-64	2492	GRSD, BRRI
Sugandhi dhan	7063	Nawabganj	OvalTAPL-2990	2990	GRSD, BRRI
Kalijira (long grain)	4358	Khulna	KalijiraTAPL-68	2496	GRSD, BRRI
Jesso balam TAPL-25	2454	GRSD, BRRI	KalijiraTAPL-74	2501	GRSD, BRRI
Dakshahi	983	Khulna	Kalobakri	2108	Narsingdi
Hatisail TAPL-101	2528	GRSD, BRRI			

Aroma test

Aroma was detected by sniffing and was scored as non-scented, lightly scented, and scented following 1.7% KOH based method (Sood and Siddiq, 1978).

Statistical analysis

Twenty-eight qualitative data were transformed to binary form described by Sneath and Sokal (1973). For qualitative traits, the presence and absence of the different variants were scored as 1 and 0 respectively. The data analysis was done using the NTSYS-pc version 2.2 (Rohlf, 2002).

RESULTS AND DISCUSSION

Qualitative traits characterization

Agro-morphological characterization is an important activity to evaluate the utilization of the germplasm collection in a genebank (Islam *et al*., 2018a). The diversity in crop varieties is essential for agricultural development for increasing food production; poverty alleviation and promoting economic growth. The present study was aimed at identifying distinct qualitative traits for aromatic rice germplasm. Polymorphism was found in 25 of the 28 qualitative traits studied; the non-polymorphic traits were of ligule colour, ligule shape and auricle colour (Table 2). Figure 1 presents variation in grain morphology of some aromatic rice germplasm. Among the 113 aromatic germplasm, 87.61% showed blade pubescence, 97.35% green blade colour, 95.58% green basal leaf sheath colour, 96.46% horizontal leaf angle, 95.58% pale green of collar colour, 94.69% has well exerted panicle and 88.49% has white colour of stigma. The present study results reveal that all aromatic rice germplasm have the same ligule colour, shape and auricle. Also the variability in most of the observed qualitative traits of aromatic rice germplasm was exhibited in our study. Similar studies were also reported by other researchers (Ahmed *et al*., 2016; Mau *et al*., 2017; Akter *et al*., 2017 and Islam *et al*., 2017). However, Islam *et al*. (2018a) found that variation for leaf blade colour, lemma-palea colour, apiculus colour, lemma-palea pubescence and seed coat colour in similar named of aromatic rice landraces. Similarly, genetic variability in *Kartiksail* rice accessions of Bangladesh using qualitative agro-morphological character was also reported by Ahmed *et al*. (2015).

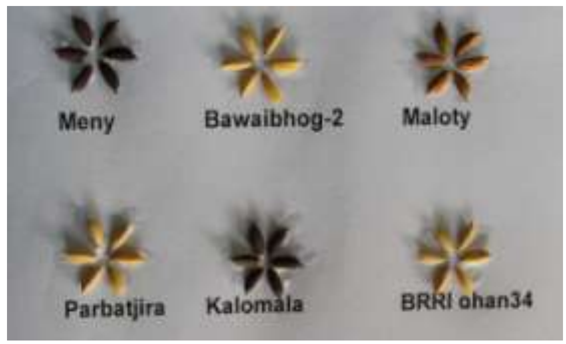

Fig. 1. Variation in grain morphology of some aromatic rice germplasm.

Cluster analysis based on 28 qualitative traits

The dendrogram were constructed on the basis of data generated from the 28 qualitative traits. Genetic distance ranged from 0.00 to 2.17 which revealed significant differences among test germplasm. The 113 aromatic germplasm were grouped into 10 clusters. As evident from Figure 2 and Table 3, the highest numbers of germplasm (96) were found in cluster IXd, 2 was found in cluster III, IV and VI, 3 were in IXc and the lowest number of genotypes (1) in cluster I, II,V, VII, VIII, IXa, IXb and X, respectively. Cluster IX consisted of four sub-clusters (IXa, IXb, IXc and IXd). Cluster IX sub-clusters IXa, IXb, IXc and IXd consisted of 1, 1, 3 and 96 aromatic germplasm, respectively. Similarly, Hossain (2008) observed 10 clusters by using UPGMA clustering method in 78 aromatic and fine grain landraces of rice genotypes. Two germplasm namely Kalgochi and Buchi in cluster IV were found similarity in 26 of the 28 qualitative traits studied and had very long awn (>20 mm). Bashful, Khazar,

Table 2. Classification of aromatic germplasm based on 28 qualitative characters.

Character	Classification	Frequency	Number of aromatic germplasm	Frequency %
Blade pubescence	01. Glabrous	2	105,95	1.77
	02. Intermediate	12	20,30,67,73,104,106,107,109,110,111,112,113	10.62
	03. Pubescent	99	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,68,69,70,71,72,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,96,97,98,99,100,101,102,103,108	87.61
Blade colour	01. Pale green	01	84	0.88
	02. Green	110	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,104,105,106,107,108,109,110,111,112,113	97.35
	03. Dark green	02	53,103	1.77
Leaf sheath: anthocyanin colour	01. Absent	108	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,109,110,111,112,113	95.58
	09. Present	05	20,66,86,87,108	4.42
Basal leaf sheath colour	01. Green	108	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,109,110,111,112,113	95.58
	03. Light purple	03	20,86,87	2.65
	04. Purple	02	66,108	1.77
Leaf angle	01. Erect	03	10,59,72,103	3.54
	05. Horizontal	110	1,2,3,4,5,6,7,8,9,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,60,61,62,63,64,65,66,67,68,69,70,71,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,104,105,106,107,108,109,110,111,112,113	96.46
Flag leaf angle	01. Erect (<30°	02	72,103	1.77
	03. Semi erect(<30-45°)	03	10,59,107	2.65
	05. Horizaontal (<46-90°)	104	1,4,5,6,8,9,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,60,61,62,63,64,65,66,67,68,69,70,71,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,104,105,106,108,109,110,111,112,113	92.04
	07. Descending (>90°)	04	2,3,7,36	3.54

Table 2. Continued.

Character	Classification	Frequency	Number of aromatic germplasm	Frequency %
Ligule colour	01. White	113	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113	Nil
Ligule shape	02. 2- cleft	113	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,10,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113	Nil
Collar colour	01. Pale green	108	2,3,4,5,6,7,8,9,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,95,96,97,98,99,100,101,102,103,104,105,106,107,109,110,111,112,113	95.58
	03. Purple	05	1,10,66,94,108	4.42
Auricle colour	01. Pale green	113	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113	Nil
Culm anthocyanin colour	01. Absent	110	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,109,110,111,112,113	96.46
	09. Present	04	20,66,86,108	3.54
Culm Angle	01. Erect (<30^0)	33	2,3,5,7,12,21,22,27,35,36,40,41,43,44,46,47,48,52,53,57,60,61,62,63,64,65,66,72,92,99,102,103,105	29.21
	03. Intermediate	68	4,6,8,9,10,11,13,14,15,16,17,19,20,23,24,25,26,29,30,31,32,33,34,37,38,39,42,45,49,51,54,55,56,58,59,68,69,70,71,73,74,77,78,79,80,81,82,84,85,86,87,88,89,90,91,93,94,95,96,97,98,100,101,104,106,108,110,112	60.18
	05. Open	12	1,18,28,50,67,75,76,83,107,109,111,113	10.62
Internode colour	01. Green	89	4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,68,69,70,71,72,73,74,79,80,81,83,84,86,87,90,92,93,94,95,96,98,99,100,101,102,103,106,113	78.76
	02. Light gold	20	2,3,67,75,76,77,78,82,85,88,89,91,97,104,105,107,109,110,111,112	17.71
	03. Purple lines	03	1,20,108	2.65
	04. Purple	01	66	0.88
Culm	01. Strong	03	53,72,103	2.65

Table 2. Continued.

Character	Classification	Frequency	Number of aromatic germplasm	Frequency %
strength	03. Moderately strong	01	104	0.88
	05. Intermediate	18	2,25,43,45,46,60,77,78,79,80,84,95,96,97,102,105,106,110	15.93
	07. Weak	68	1,,3,4,5,6,7,8,9,10,11,13,14,15,16,17,19,20,24,26,27,28,29,30,41,47,52,54,56,58,59,61,63,64,65,66,67,68,69,71,73,74,75,76,81,82,83,85,86,87,88,89,90,91,92,93,94,98,99,100,101,107,108,109,111,112,113	60.18
	09. Very weak	25	12,18,21,22,23,31,32,33,34,35,36,37,38,39,40,42,44,48,49,50,51,55,57,62,70	22.12
Panicle type	01. Compact	09	10,19,20,25,47,59,72,103,110	7.96
	05. Intermediate	97	1,4,5,6,7,8,9,11,12,13,14,15,16,17,18,21,22,23,24,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,48,49,50,51,52,53,54,55,56,57,58,60,61,62,63,64,65,66,67,68,69,70,71,73,74,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,104,105,106,107,112,113	85.84
	09. Open	07	2,3,75,76,108,109,111	6.19
Secondary branching	01. Light	68	1,2,3,6,7,8,9,10,12,13,14,15,17,18,21,22,23,25,26,28,29,37,38,39,40,41,43,44,45,48,49,50,51,52,53,54,55,57,59,60,61,62,63,64,66,67,70,71,72,76,77,79,81,86,89,90,91,101,103,104,106,108,109,110,111,112,113,114	59.29
	02. Heavy	46	4,5,11,16,19,20,24,27,30,31,32,33,34,35,36,42,46,47,56,58,65,68,69,73,74,75,78,80,82,83,84,85,87,88,92,93,94,95,96,97,98,99,100,102, 105,107	40.70
Panicle exsertion	01. Well exserted	107	1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,54,55,56,57,58,59,60,61,64,65,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113	94.69
	03. Moderately well exserted	05	6,28,53,62,63	4.42
	05. Just exserted	01	66	0.88
Spikelet: awns in the spikelet	01. Absent	78	1,2,4,5,6,7,11,12,14,15,16,17,19,20,21,23,25,26,27,28,32,33,36,37,39,40,42,43,45,46,50,51,53,55,56,57,58,62,63,64,65,68,69,72,73,74,75,76,77,78,79,80,82,84,85,86,87,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112	69.03
	09. Present	35	3,8,9,10,13,18,22,24,29,30,31,34,35,38,41,44,48,49,52,54,59,60,61,62,66,67,70,71,81,83,88,89,90,91,113	30.97
Spikelet: awn length	01. Very short (<2mm)	11	8,29,34,38,48,49,62,88,89,90,91	9.73
	03. Short (2-5 mm)	02	41,43	1.77
	05. Medium (5-10 mm)	07	3,30,35,44,54,70,81	6.19
	07. Long (11-20 mm)	02	31,67	1.77
	09. Very long (>20mm)	14	9,10,13,18,22,24,52,59,60,61,66,71,113	11.50
Distribution of awning	01. Tip only	17	3,8,29,30,34,35,38,41,44,48,49,62,70,81,88,89,90,91	15.04
	03. Upper half only	06	13,24,31,54,67,83	5.30

Table 2. Continued.

Character	Classification	Frequency	Number of aromatic germplasm	Frequency %
	05. Whole length	12	9,10,18,22,52,59,60,61,66,71,113,114	10.61
Awn colour	01. Straw	14	3,18,22,35,38,41,48,49,62,67,70,71,88,89	12.39
	02. Gold	03	66,90,91	2.65
	03. Brown	11	8,9,10,29,30,31,52,54,60,61,113	9.73
	04. Red	02	44,83	1.76
	05. Purple	05	13,24,34,59,81	4.42
Apiculus colour	01. White	11	7,28,60,67,68,72,85,103,105,106,107	9.73
	02. Straw	49	2,3,4,11,12,15,18,21,22,32,35,36,37,38,39,41,44,45,47,48, 49,53,55,56,58,62,63,64,65,69,70,71,74,75,80,82,83,88,89, 90,91,93,95,96,97,100,101,110	43.36
	03. Brown	19	5,8,29,52,54,57,61,73,76,81,83,87,99,104,108,109,111,112 ,113	16.81
	05. Red apex	02	98,102	1.77
	06. Purple	33	1,6,9,10,13,14,16,17,19,20,23,24,25,26,27,30,31,33,34,40, 42,43,46,50,51,58,59,66,77,78,79,84,86,92,94	29.20
Stigma colour	01. White	100	1,2,3,4,5,6,7,9,10,11,12,13,14,15,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31,32,33,34,36,37,38,39,40,41,43,45,46, 47,53,54,55,56,58,59,60,61,62,63,64,65,66,67,68,69,70,71, 72,73,74,75,76,77,78,79,80,81,82,83,84,85,88,89,90,91,92, 93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,10 8,109,110,111,112,113	88.49
	04. Light purple	06	8, 35, 42, 48, 49, 52	5.31
	05. Purple	07	16, 44, 50, 51, 57, 86,87	6.19
Lemma and palea colour	0. Straw	54	3,4,7,11,14,17,18,19,21,22,23,24,27,32,35,36,38,39,40,41, 46,48,49,50,52,53,55,56,58,60,63,65,67,68,69,70,71,72,74, 75,80,81,82,84,85,86,90,91,92,95,97,103,104,105,106	47.78
	01. Gold	13	2, 43, 62, 64, 66, 87,88,89, 93, 96, 100,101,102	11.50
	03. Brown furrows on straw	06	9, 29, 30, 45, 78, 108	5.31
	04. Brown	11	26, 28, 33, 52, 54, 57, 73,77,79, ,94,99,	9.73
	05. Reddish to light purple	09	12, ,15,25,37,44,47,98,107,110	7.96
	06. Purple spots on straw	06	10,20,31,34,51,59	5.31
	07. Purple furrows on straw	01	42	0.88
	08. Purple	06	1, 5,6, 13, 16, 76	5.31
	09. Black	07	8, 61, 83, 109, 111,112,113	6.19
Lemma and palea pubescence	01. Glabrous	07	5, 23, 32, 38, 53, 58, 89	6.19
	02. Hairs on lemma keel	01	113	0.88
	03. Hairs on upper portion	05	4, 7, 11, 21, 37	4.42

Table 2. Continued.

Character	Classification	Frequency	Number of aromatic germplasm	Frequency %
	04. Short hairs	75	1,2,3,6,8,9,13,14,15,16,17,18,19,20,22,24,25,26,27,28,29,30,31,33,34,35,36,39,10,41,42,44,46,47,48,49,50,51,52,54,55,56,65,66,68,69,70,72,74,75,77,78,79,80,81,82,83,84,85,86,87,88,92,93,95,97,100,101,102,103,104,105,106,107, 110	66.37
	05. Long hairs	25	10,12, 43, 45, 57, 59, 60,61,62,63,64, 67, 71,73,76,90,91, 94, 96, 98,99, 108,109, 111,112	22.12
Seed coat (bran) colour	01. White	79	2,3,7,9,10,11,14,17,18,19,20,21,22,23,24,25,26,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,46,47,48,49,50,53,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,75,80,82,84,85,86,87,88,89,91,92,93,94,96,97,98,101,103,105,106,107, 110, 113	69.91
	02. Light brown	32	1, 4,5,6, 8, 12,13, 15,16, 27, 29, 45, 51,52, 54, 73,74, 76,77,78,79, 81, 83, 90, 95, 99,100, 102, 104, 109, 111,112	28.31
	05. Red	02	28,108	1.76
Leaf senescence	01. Late and slow	03	45, 50, 61	2.65
	05. Intermediate	13	9,10, 14, 43, 55, 58, 60, 62,63, 72, 80, 103, 113	11.50
	09. Early and fast	97	1,2,3,4,5,6,7,8,11,12,13,15,16,17,18,19,20,21,22,23,24,25, 26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,44,46, 47,48,49,51,52,53,54,56,57,59,64,65,66,67,68,69,70,71,73, 74,75,76,77,78,79,81,82,83,84,85,86,87,88,89,90,91,92,93, 94,95,96,97,98,99,100,101,102,104,105,106,107,108,109,110,111,112	85.84
Decorticated grain: Scent (aroma)	0. Non scented	12	28,29, 45, 50, 53, 56, 64, 66, 81, 82, 86, 88	10.62
	01. Lighty scented	35	1,2,3,6,7,23,24,25,27,37,38,43,67,72,83,84,87,89,90,91,92, 93,94,95,96,97,98,99,100,102,103,104,105, 107, 110	30.97
	02. Scented	66	4,5,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,26,30,31,32,33,34,35,36,39,40,41,42,44,46,47,48,49,51,52,54,55,57,58,59,60,61,62,63,65,68,69,70,71,73,74,75,76,77,78,79,80, 85, 101, 106, 108,109, 111,112,113	58.41

Sugandhi dhan, Jirabuti, Elai, Dhan chikon, Malshira and Sakor were clustered in indivisul group I, II, V,VII, VIII and sub-cluster IXa, IXb and X respectively. The germplasm like as Jirabuti, Khazar, Thakurbhog, Khuti Chikon and Bashful had special qualitative traits such as anthocyanin colour of leaf sheath. On the other hand, Jirabuti, Khazar, Thakurbhog and Bashful had anthocyanin colour of culm nodes except Khuti chikon. Cluster IX, sub-clusters IXa, IXb, IXc and IXd were sub-grouped according to their special distinctive qualitative traits and germplasm in the different sub-clusters were closely distant to each other. In general, most of the germplasm fall in fourth major sub-cluster IXd contained 96 aromatic rice germplasm. Basal leaf sheath colour, leaf angle, flag leaf angle, clum angle, culm strength, panicle type and leaf senescence of these 96 germplasm were very close. Therefore, all closely related germplasm were found in same sub-cluster IXd. Parikh *et* *al.* (2012) also found that majority of the germplasm to possess green basal leaf sheath colour (84.5%), green leaf blade colour (86.8%), green collar colour (97.3%), white ligule colour (94.7%), light green auricle colour (97.3%), white apiculus colour (53.9%), white stigma colour (94.7%) and awnless (72.3%) in 71 aromatic rice germplasm. Moreover, most of the cultivated aromatic rice genotypes are photosensitive and taller types having yield potentiality of 2-3 t ha^{-1} and grown during T. Aman season in the rainfed low land ecosystem in Bangladesh (Islam *et al.*, 2016). The two germplasm namely Dhan chikon and Malshira were found in sub-cluster IXa and IXb respectively. Ranisalut, Gandhakusturi, Thakurbhog were found in sub-cluster IXc. Interestingly, BRRI dhan50 and BU dhan2R, which have similiar plant type, yield and grain characters, placed in the same cluster III. Among the other cluster, Sakor, a slight aromatic rice germplasm grown mainly in Mymensingh region and with no relation to the other germplasm, formed a single cluster. A study conducted by Bisne and Sarawgi (2008) to characterize 32 aromatic rice accessions of Badshahbhog group from Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, Chhattisgarh, germplasm, found the highest variation among accessions for the traits leaf blade colour, lemma and palea colour, apiculus colour, and lemma and palea pubescence.

Moreover, aroma evaluation revealed that 67 germplasm were scented, 34 were lightly scented, while the rest 12 germplasm were non-scented (Table 4). For example, local variety including aromatic rice germplasm occupied about 12.16% of the rice growing area in Bangladesh (Islam *et al.*, 2016). Among the aromatic rice germplasm, Chinigura is the predominant one that covers more than 70% farms in the northern districts of Naogaon and Dinajpur. In these districts, 30% of rice lands were covered by aromatic rice varieties during Aman season. The other important aromatic rice varieties are Kalijira (predominant in Mymensingh) and Kataribhog (predominant in Dinajpur) (Baqui *et al.*, 1997).

Principal co-ordinate analysis (PCoA)

The three dimensional (3D) graphical views of principal co-ordinate analysis (PCA) showed the spatial distribution of the germplasm. The germplasm namely Bashful, Khazar, Jirabuti, Sakor, Kutichikon, Thakurbhog-2, Black TAPL-554, Kalgochi and Buchi were found to be distance from the centroid (Fig. 3) while the rest were close to the centroid. The results indicated that the germplasm that were placed far away from the centroid were more genetically diverse, while the genotypes that were placed near the centroid possessed more or less similar genetic background. Similar findings were also reported by other authors (Siddique *et al.*, 2016a, 2016b). However, centroid may be defined as the vector representing the middle point of the cluster which contained at least one number for each variable. The connecting lines between each germplasm and the centroid represented eigenvectors for the respective germplasm.

Fig. 2. Dendrogram of 113 test germplasm based on 28 qualitative traits.

Table 3. Cluster distribution of 113 aromatic germplasm based on 28 qualitative traits.

Cluster	No. of germplasm	Name of germplasm
I	1	Bashful
II	1	Khazar
III	2	BRRI Dhan50, BU dhan2R
IV	2	Kalgochi ,Buchi
V	1	Sugandhi dhan
VI	2	Thakurbhog-2, Khuti chikon
VII	1	Jirabuti
VIII	1	Elai
IXa	1	Dhan chikon
IXb	1	Malshira
IXc	3	Ranisalut, Gandhakusturi, Thakurbhog
IXd	96	Sagardana, Nunia, Chini Sagar (2), Meny, Tilkapur, Binnaphul, Kalobhog, Jabsiri, Chinisakkor, Chiniatob, Noyonmoni, Saubail, Chinniguri, Kalomala, Begunmala, Gopalbhog, Tulsimoni, Khirshabuti, Rajbut, Soru kamina, Kamini soru, Doiarguru, Premful, Begun bitchi, Gua masuri, Luina, Lal Soru, Chini Kanai, Kalijira (short grain), Rajbhog, Philliphine kataribhog, Baoibhog, Baoijhaki, Jirabhog (Bolder), Chinigura, Tulsimala, Bashmati 370, Uknimodhu, Jira dhan, Sakkorkhora, Badshabhog, Jirakatari, Desikatari, Tulsimaloty, Raduni pagal, Kalijira (long grain), Jesso balam TAPL-25, Dakshahi, Hatisail TAPL-101, Khasa, Awned TAPL-545, Black TAPL-554, Straw TAPL-554, Dubsail, Duksail, Khaskani, Basmati sufaid 106, BR5, BRRI dhan34, BRRI dhan37, BRRI dhan38, Khasa Mukpura, Uknimodhu, Bawaibhog-2, Chiniatob-2, Tilokkachari, Begunbitchi-2, Chinairri, Bhatir cikon, Gordoi, Dolagocha, Kalonunia, Badshabhog-2, Sunduri samba, Basmati, Basmati 37, Basnatu sufaid 187, Tulsimala-2, Chinisail, Sadagura, Modhumadab, Parbatjira, Chinikanai-2, Meedhan, Gobindhabhog, Kataribhog, Fulkari, Padmabhog, Dudsail, Sakkorkhana, Maloti, KalijiraTAPL-64, OvalTAPL-2990, KalijiraTAPL-68, KalijiraTAPL-74, Kalobakri
X	1	Sakor

Table 4. Classification of aromatic germplasm based on sensory test.

Decorticated grain: scent aroma	Number of germplasm	Name of germplasm
Non scented	12	Elai, Gua masuri, Gandha kusturi, Thakurbhog, Sugandhi dhan, Dakshahi, Duksail, Khazar, Gordoi, Dolagocha, Thakurbhog-2, Sunduri samba
Light scented	34	Sakor, Sagardana, Nunia, Tilkapur, Binaphul, Soru Kamina, Kamini soru, Doiarguru, Begun bichi, Baoi jhaki, Jirabhog (Bolder), Ranisaluit, Basmati sufaid-106, BRRI dhan50, Kalonunia, Dhan chikon, Khuti chikon, Basmati- 37, Basnatu sufaid-187, Tulsimala-2, Chinisail, Malshira, Sadagura, Modhumadab, Parbatjira, Chinikanai-2, Meedhan, Gobindhabhog, Fulkari, BU Dhan2R, Padmabhog, Dudsail, Maloti, OvalTAPL-2990
Scented	67	Chini Sagar (2), Meny, Kalobhog, Jabsiri, Kalgochi, Chinisakkor, Chini atob, Noyonmoni, Saubail, Kolomala, Chinniguri, Begunmala, Gopalbhog, Tulsimoni, Jirabuti, Khirshaboti, Rajbut, Premful, Luina, Lal Soru, Chini kanai, Kalijira (short grain), Rajbhog, Phillipine kataribhog, Baoibhog, Chinigura, Tulsimala, Bashmati 370, Uknimodhu, Jira dhan, Sakkor khora, Badshabhog, Jirakatari, Desi katari, Tulsimaloty, Radhuni pagal, Kalijira (long grain), Jesso balam, Hatisail, Khasa, Buchi, AwnedTAPL-545, BlackTAPL-554, StrawTAPL-500, Dubsail, Khaskani, BR5, BRRI dhan34, BRRI dhan37, BRRI dhan38, Khasa Mukpura, Uknimodhu, Bawaibhog-2, Chiniatob-2, Tilokkachari, Begunbichi-2, Chinairri, Bhatir cikon, Badshabhog-2, Basmati, Kataribhog, Sakkorkhana, Bashful, KalijiraTAPL-64, Oval TAPL-2990, Kalijira TAPL68, Kalijira TAPL74, Kalobakri

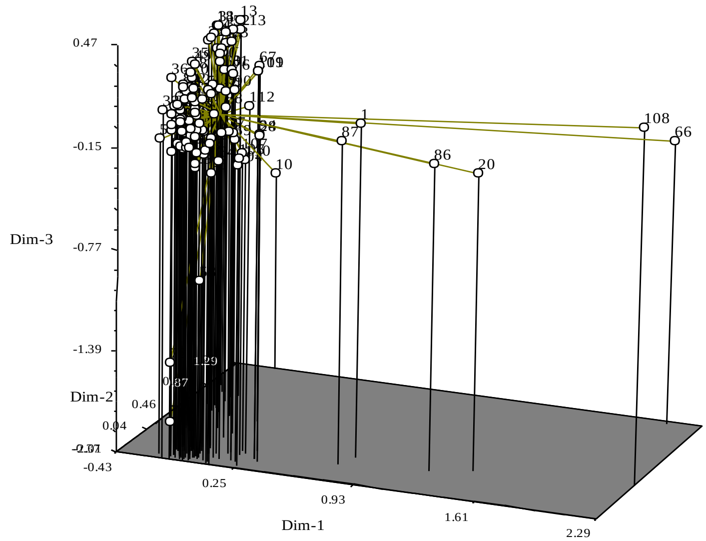

Fig. 3. There-dimensional view of principal co-ordinate analysis (PCoA) of 113 aromatic germplasm with 28 qualitative traits.

CONCLUSIONS

Traditional aromatic rice germplasm, which is highly chosen by consumers needs to be characterized that can help in varietal development purpose and their conservation (Islam *et al.,* 2018b). No duplicates were identified among the studied germplasm for qualitative traits in the cluster analysis. Aroma is an important trait, has high demand in the global market. The evaluation of aroma showed that 67 germplasm were scented, 34 were lightly scented and 12 were non-scented type. The principal co-ordinate analysis (PCoA) showed the germplasm namely Bashful, Khazar, Jirabuti, Sakor, Kutichikon, Thakurbhog-2, Black TAPL-554 and Kalgochi were found to be the distance from the centroid and they were more genetically diverse. For lemma-palea colour, nine different types were detected while for apiculus colour of grain, six different types were recorded and colour of awn, six different types were observed, suggesting the presence of exclusive variability and unique feature of the traditional short grain aromatic rice germplasm in Bangladesh. Finally, it can be concluded that molecular characterizations of the studied germplasm are required for QTL mapping and validating the presence of candidate genes responsible for valuable characters.

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Effect of Planting Time on Sheath Blight Disease of Rice in Bangladesh

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ABSTRACT

Sheath blight (ShB) caused by *Rhizoctonia solani* is one of the major disease of rice (*Oryza sativa* L.) in Bangladesh. Effect of planting time on ShB disease of BRRI dhan49 was observed at the experimental plots of Bangladesh Rice Research Institute, Gazipur. Two field experiments were conducted to develop management strategy for controlling ShB during T. Aman 2010-11 seasons. Four planting dates *viz.* 15 July, 30 July, 15 August and 30 August were imposed to record the effect of planting time on incidence and severity of ShB disease on BRRI dhan49. Significant differences on the Relative Lesion Height (RLH) among the treatments were observed during both 2010 and 2011 seasons. For both the seasons, the highest RLH was recorded in plots transplanted on 15 August (62.1% in 2010 and 61.2% in 2011) because of the remaining high temperature, rainfall and humidity and the lowest in plots transplanted on 30 July (19.4% for both). Similarly, the maximum severity score was recorded in 15 August transplanting (7) and the minimum in 30 July (1) respectively. Percent disease index (PDI) was also varied significantly among the treatments for both the seasons. During both the years, the maximum PDI was recorded in 15 August (76.5 and 75.2% respectively) and the minimum in 30 July transplanting (20.4 and 20.1 respectively). However, the highest number of filled grains panicle^{-1} was counted in 30 July (151), followed by15 July transplanting (145) during 2010. But, it was the highest in 30 July (141), followed by 15 August transplanting (136) during 2011. Again for both the seasons, the lowest filled grains panicle^{-1} was recorded in 30 August transplanting (116 and 127). Similarly for both the years, the maximum grain yield was observed in 30 July (6.29 and 5.82 t ha^{-1} respectively), followed by 15 July (5.67 and 5.17 t ha^{-1}) and the lowest in 30 August transplanting (3.80 and 4.27 t ha^{-1} respectively). However, 1000 grain weight was 20 g in each date of transplanting during both the seasons. Finally, Integrated Disease Management (IDM) packages need to be developed by using appropriate planting time, cultural practices and fungicides to control ShB disease of rice.

Key words: Planting time, sheath blight incidence, rice

INTRODUCTION

Sheath blight (ShB) disease of rice, caused by *Rhizoctonia solani* Kuhn is a destructive disease worldwide (Nagarajkumar *et al.*, 2004). The pathogen has a wide host range and can infect plants belonging to more than 32 families and 188 genera (Gangopadyay and Chakrabarti, 1982). In Bangladesh, ten rice diseases are considering as major (Miah and Shahjahan, 1987) and ShB is one of them. ShB infected 20.8% of the plant populations with an estimated yield loss even up to 50% (Anonymous, 2006). It is prevalent in almost all rice growing areas and seasons of Bangladesh, but the highest intensity was found in transplanted Aus, followed by T. Aman and Boro seasons (Anonymous, 2018). Therefore, for sustainable rice production, minimizing both the ShB epidemics and its yearly crop losses are essential in Bangladesh. Development of ShB disease depends on climatic factors, host and soil components (Damicone *et al.*, 1993). Temperature and relative humidity (Leano, 1993), soil, inoculum of *Rhizoctonia solani* (Lakpale *et al.*, 1994), plant density (Dilla, 1993) and physiologic condition of rice plants (Hashiba *et al.*, 1977) are important for the development of ShB disease of rice.

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The peak stage of ShB disease is during flowering when the rice canopy is most dense, forming a microclimate favourable to pathogen growth and spread (Brooks, 2007). ShB infection during flowering or heading stage causes a reduction of total seed weight due to lower number of filled grains and consequently lower yield (Nagarajkumar *et al.*, 2004). Other factors for ShB disease severity are the growth stage at infection, cultivar resistance and cultural practices (Groth *et al.*, 1992). Both seedling and adult plants are equally affected by ShB, but losses are significantly higher in seedling stage. However, the disease severity and yield loss is higher during booting stage as compared to tillering, maximum tillering or panicle initiation stage. Besides, Wu *et al.*, (2012) reported that lodging alters the normal rice canopy design, affecting photosynthetic ability and total biomass production and causes epidemics.

Temperature and humidity are the two main factors for ShB disease development. Due to global warming, air temperature is increasing day by day, which is also favourable for rapid ShB disease development. Depending on plant age, time of infection and severity, it causes yield loss of 5.9 to 69% (Naidu, 1992). Under favourable conditions, yield losses due to ShB disease range from 4 to 50% (Groth *et al.*, 1991; Marchetti and Bollich, 1991). But, the average incidence of ShB in Bangladesh is about 20.3% (Ali *et al.*, 2003) and may ranges from 14 to 31% under farmer's field condition (Shahjahan *et al.*, 1986).

The control of ShB disease is depended mainly on fungicides by the farmers. But, it is not considered sustainable due to its toxic residual effects, potential risk of emergence of races of the pathogen overtime and different environmental hazards. Ashrafuzzaman *et al.* (2005) also emphasized on different management options to control ShB disease. Therefore, there is an ample scope to use different cultural practices for managing ShB. The optimum planting time is one of the important options, because, ShB disease development can be avoided in optimum planting time, as comparing to the late transplanting, particularly in Boro season (Hossain and Mia, 2001). Therefore, considering the above facts, the present study was designed to determine the optimum planting time of rice for managing the ShB disease of rice with the aim of recommending IDM strategy for rice field in Bangladesh.

MATERIALS AND METHODS

Field experiment, design and treatment. Two experiments were conducted at BRRI experiment field in Gazipur under artificial inoculation condition during T. Aman 2010-11 seasons. A levee was made surrounding the plots to maintain standing water up to 5.0 cm inside. Land was prepared 15 days before transplanting. Ploughing and cross ploughing followed by laddering was done by power tiller. Weeds were cleaned manually. Thirty-day-old and 2-3 seedlings per hill of BRRI dhan49 were transplanted with 20 cm × 15 cm spacing. The experiment was laid in RCBD with four replications. The individual plot size was 2.0 × 2.0 m^2. Each plot was separated from the other by a two-hill-wide border. The blocks were separated by a 0.5 m path including a levee. Fertilizers were applied @ 405: 150: 202: 135: 10 g $decimal^{-1}$ of urea, TSP, MOP, gypsum and zinc sulphate respectively. All fertilizers were applied in basal, except urea. For agronomic practices such as weed, irrigation, drainage and insect management current standard recommendations were followed (Anonymous, 2010). Four transplanting dates were evaluated as treatments: T_1= 15 July, T_2= 30 July, T_3= 15 August and T_4= 30 August.

Preparation of inoculum. One hundred PDA plates in glass petridishes were prepared following the standard procedure. The fungus (*Rhizoctonia solani)* was grown in the petridishes containing PDA medium and incubated for seven days at room temperature (25 to 30°C) for growth and development of the pathogen.

Inoculation of pathogen. Inoculations were done at maximum tillering stage (Bhaktavatsalam *et al.,* 1978). The plants were inoculated with *Rhizoctonia solani* culture (7 days) grown on PDA medium. Prior to inoculation, eight hills were tagged randomly in the central area of each plot. Inoculation was done by inserting a piece of culture medium (cutting the culture medium into eight pieces) at the middle of each hill in the afternoon, colonized by the ShB pathogen in a tagged rice hill and maintained standing water onward of the crop growth to maintain high moisture below canopy level for disease development (Sharma and Teng, 1990).

Data collection. Disease data were collected at the hard dough stage. Twenty-five hills were selected at random from each experimental unit. Number of infected tillers and hills were counted. Incidence was recorded by tiller infection and expressed in percentage, while severity by relative lesion height (RLH) and percent disease index (PDI) (McKinney, 1923). Standard Evaluation System (SES) for rice (IRRI, 2002) was used for calculation of PDI. Data were recorded for each treatment following SES for rice in 0-9 scale (Table 1).

Data on total tiller, infected tiller, plant height, panicles m^{-2}, filled grain, unfilled grain, 1000 grain weight and grain yield were recorded. Grain yield was expressed in t ha^{-1}.

Table 1. Standard Evaluation System for ShB disease of rice.

SCALE (based on relative lesion height)	
0	No infection observed
1	Lesions limited to lower 20% of the plant height
3	20-30%
5	31-45%
7	46-65%
9	More than 65%

Note: The relative lesion height is the average vertical height of the uppermost lesion on leaf or sheath expressed as a percentage of the average plant height.

$$RLH = \frac{\text{Lesion height (cm)}}{\text{Plant height (cm)}} \times 100$$

$$PDI = \frac{\text{Total rating}}{\text{No. of observation} \times \text{Maximum grade}} \times 100$$

Statistical analysis. The data were subjected to statistical analysis and ANOVA (analysis of variance) was constructed by SPSS 2.05 programme. Microsoft Excel 2010 was used for data management. The treatment means were compared by LSD test at probability level P=0.05.

Weather data. The maximum and minimum air temperature, relative humidity and rainfall data from 2010 to 2011 were collected from meteorological station at BRRI, Gazipur.

RESULT AND DISCUSSION

Effect of planting time on ShB disease incidence and severity. Table 2 shows the effect of planting time on the development of ShB disease of rice during T. Aman 2010. Significant differences on the RLH among the transplanting dates were observed. The highest RLH was recorded in plots transplanted on 15 August (62.1%) and the lowest was in plots transplanted on 30 July (19.4). However, the RLH was 22.80% in 15 July and 44.9% in 30 August transplanting. The difference in RLH between 15 July and 30 July transplanting was not significant. But RLH of 30 August was significantly lower from 15 August transplanting and significantly higher over 15 July and 30 July transplanting. However, higher RLH was found in 15 August than 15 July. Severity score of ShB disease was also the maximum in 15 August transplanting (7). It was 5 in plots transplanted on 30 August and 3 in plots transplanted on 15 July. However, the minimum score of severity (1) was in 30 July transplanting. PDI varied significantly among the transplanting dates. The maximum PDI was recorded in 15 August (76.5%) and the minimum in 30 July transplanting (20.4). Significant differences in PDI were observed between 15 July and 30 July, 30 July and 15 August, 15 July and 15 August and 15 and 30 August transplanting respectively.

Table 3 shows the effect of transplanting time on development of ShB disease of rice during T. Aman 2011. RLH was as high as 61.20% in 15 August and 44.20% in 30 August transplanting. However, the RLH was 23.0% in 15 July and 19.40% in 30 July transplanting. The difference in RLH between these two transplanting dates was not significant. Similarly difference between 15 July and 30 July transplanting was not significant. But difference between 15 July and 15 August, 15 July and 30 August, 30 July and 15 August as well as 30 July and 30 August transplanting were significant. The minimum (1) severity score of ShB was recorded in 30 July transplanting and the maximum (7) in 15 August transplanting followed by 5 in 30 August and 3 in 15 July transplanting. PDI also differed significantly among the transplanting dates of BRRI dhan49. It was the maximum in 15 August (75.23%) and the minimum in 30 July (20.14) transplanting. Significant variation in PDI between 30 July and 30 August (59.7%) transplanting was recorded. Likewise the variation in PDI between 15 July (37.6%) and 15 August was significant.

Table 2. Effect of planting time of BRRI dhan49 on the development of ShB disease during T. Aman, 2010.

Treatment	RLH (%)	Severity score	PDI
T_1	22.80c	3	40.20c
T_2	19.44c	1	20.40d
T_3	62.10a	7	76.50a
T_4	44.88b	5	68.40b
LSD (P=0.05)	11.88		4.60

T_1=15 July, T_2=30 July, T_3=15 August and T_4=30 August transplanting. Means followed by the same letter in a column did not differ significantly at the 5% level by LSD, PDI=Percent disease index, RLH=Relative lesion height. Severity score 1=Lesions limited to lower than 20% of plant height, 3=20-30%, 5=31-45%, 7=46-65% and 9=More than 65%.

Table 3. Effect of planting time of BRRI dhan49 on ShB disease development during T. Aman 2011.

Treatment	RLH (%)	Severity score	PDI
T_1	23c	3	37.62c
T_2	19.40c	1	20.14d
T_3	61.20a	7	75.23a
T_4	44.20b	5	59.67b
LSD (P=0.05)	15.62		10.79

T_1=15 July, T_2=30 July, T_3=15 August and T_4=30 August transplanting. Means followed by the same letter in a column did not differ significantly at the 5% level by LSD.

Effect of weather factors on planting times for ShB disease incidence and severity. It is evident from the results of the study that planting times had significant effect on ShB disease incidence and severity of rice in the fields. Significant differences on the RLH, severity score and PDI among the treatments for both the seasons were observed. The RLH, severity score and PDI were found significantly higher in 15 August transplanting than 30 July (Fig. 1) as well as 15 July transplanting (Fig. 2) during T. Aman 2010, because of the remaining high temperature, rainfall and relative humidity (9 am and 2 pm) during 15 August than 15 and 30 July 2010 respectively. Moreover, the microclimate at the

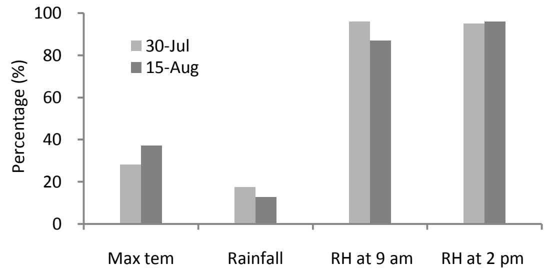

Fig. 1. Temperature, rainfall and relative humidity during 30 July and 15 August 2010.

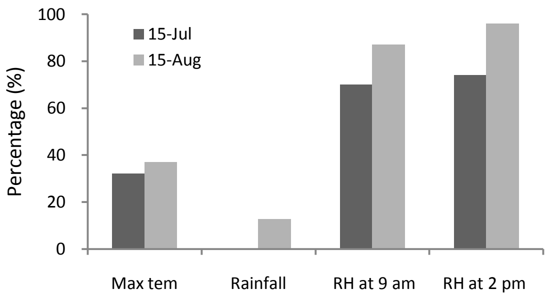

Fig. 2. Temperature, rainfall and relative humidity during 15 July and 15 August 2010.

maximum tillering stage of BRRI dhan49 became more favourable in the season due to 15 August transplanting in Bangladesh. Kozaka (1975) narrated similar observations in Japan for epidemic development of ShB. Similarly, Ui *et al.* (1976) observed that the RLH became higher under the favourable microclimate within the canopy of the rice hills.

Similarly, the RLH, severity score and PDI were also found significantly higher in 15 August transplanting than 30 July (Fig. 3) as well as 15 July transplanting (Fig. 4) during T. Aman 2011, due to higher temperature, rainfall and relative humidity (9 am and 2 pm) during 15 August than 15 and 30 July 2011 respectively.

Effect of planting time on yield components. Table 4 shows that planting time had significant effect on the yield and yield components of BRRI dhan49. Number of panicles m^{-2} was the highest (268) in 30 August transplanting and was statistically similar to 30 July (263) and 15 July (257) transplanting. However, panicles m^{-2} was significantly lower (244) in 15 August transplanting. Number of panicles m^{-2} in 15 July transplanting was statistically similar to 30 July transplanting. The highest number of filled grains $panicle^{-1}$ (151) was counted in 30 July, followed by 15 July transplanting (145) grains $panicle^{-1}$. The lowest number of filled grains $panicle^{-1}$ (116) was recorded in 30 August transplanting. However, it was 127 in 15 August and was significantly differed from that of 30 August transplanting (116). The maximum number of unfilled grains (74) was counted from a panicle in 30 August transplanting and the minimum in 30 July transplanting (39). However, it was 63 in 15 August and 45 in 15 July transplanting. The number of unfilled grains in plots transplanted on 15 July did not differ from that of 30 July, but the number of unfilled grains in 30 July and 15 August transplanting varied significantly between 15 August and 30 August transplanting. Grain yield was the maximum (6.29 t ha^{-1}) in 30 July and it was 5.67 t ha^{-1} in 15 July transplanting. The difference in grain yield between 15 July and 30 July transplanting was significant. However, the difference in grain yield between 15 August (4.17 t ha^{-1}) and 30 August (3.80) was insignificant. But, grain yield of 15 August transplanting was significantly lower than that of 15 July transplanting. Shahjahan *et al.* (1986) also reported that the losses caused by ShB disease in Bangladesh may ranges from 14 to 31% under farmer's field condition. Finally, the transplanting dates did not affect grain weight of BRRI dhan49. The weight of 1000 grains was 20 g in each transplanting date during T. Aman 2010.

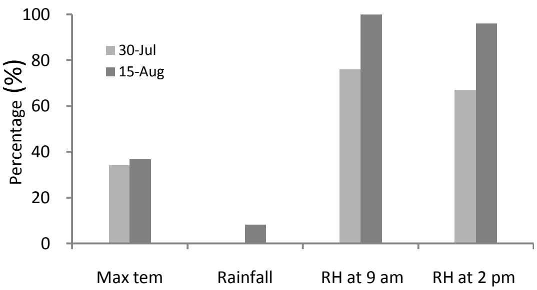

Fig. 3. Temperature, rainfall and relative humidity during 30 July and 15 August 2011.

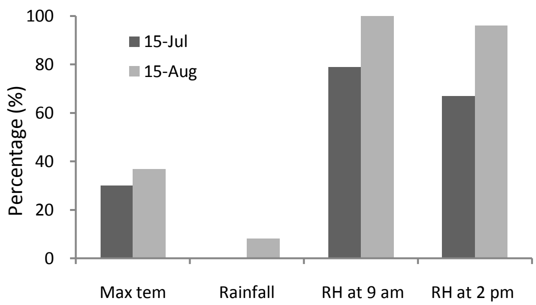

Fig. 4. Temperature, rainfall and relative humidity during 15 July and 15 August 2011.

Table 5 shows the effect of transplanting time as affected by ShB on yield and yield components of BRRI dhan49. Higher number of panicle m^{-2} (266) was counted in 30 August transplanting. The number of panicles was comparatively low (244) in 15 August transplanting. There was no difference in number of panicles m^{-2} between 30 July (263) and 30 August transplanting. Similarly, 15 July (257) and 15 August transplanting did not vary in panicle numbers m^{-2}. There was a statistical variation in number of filled grains $panicle^{-1}$ among the transplanting dates. Number of filled grains $panicle^{-1}$ was 141 in 30 July transplanting as compared to 134 in 15 July transplanting. The difference was insignificant. The lowest number of filled grains $panicle^{-1}$ (127) was counted in 30 August transplanting. Variation in number of unfilled grains was also significant. Statistically, among the dates of transplanting, the maximum number of unfilled grains (74) was counted in 30 August transplanting, which was significantly different from that in 15 August transplanting (62). Transplanting in 15 July and 30 July did not differ in number of unfilled grains. Number of unfilled grains was the lowest (39) in 30 July transplanting.

There were also significant differences among the transplanting dates for grain yield. Yield was significantly higher (5.82 t ha^{-1}) in 30 July transplanting as compared to 5.17 t ha^{-1} in case of 15 July transplanting, but the difference was not significant (Table 5). The plots transplanted on 15 August produced 4.56 t ha^{-1} grain yields and that of 30 August produced 4.27 t ha^{-1}. The difference was insignificant but the difference in grain yield between 30 July and 30 August transplanting was significant. Yield loss estimated to the range of 40.0 -1780.0 kg ha^{-1} (Ali, 2002) and 135.9 to 762.2 kg ha^{-1} (Anonymous, 2003). For different transplanting dates, a sheath infection did not affect the grain size of BRRI dhan49. The 1000 grain weight was 20 g in each transplanting date during T. Aman 2011.

Table 4. Effect of ShB disease as influenced by planting time on yield and yield components of BRRI dhan49 during T. Aman 2010.

Treatment	Panicle m^{-2}	Filled grain $panicle^{-1}$	Unfilled grain $panicle^{-1}$	1000 grain weight (g)	Yield (t ha^{-1})
T_1	257a	145a	45c	20	5.67b
T_2	263a	151a	39c	20	6.29a
T_3	244b	127b	63b	20	4.17c
T_4	268a	116c	74a	20	3.80c
LSD (P=0.05)	15.49	8.84	8.84	NS	0.55

T_1=15 July, T_2=30 July, T_3=15 August and T_4=30 August transplanting. Means followed by the same letter in a column did not differ significantly at the 5% level by LSD. NS= Not Significant.

Table 5. Effect of ShB as influenced by planting time on yield and yield components of BRRI dhan49 during T. Aman 2011.

Treatment	Panicle m^{-2}	Filled grain $panicle^{-1}$	Unfilled grain $panicle^{-1}$	1000 grain weight (g)	Yield (t ha^{-1})
T_1	257ab	134ab	45c	20	5.17a
T_2	263a	141a	39c	20	5.82a
T_3	244b	136a	62b	20	4.56b
T_4	266a	127b	74a	20	4.27b
LSD (P=0.05)	15	8.40	8.84	NS	0.80

T_1=15 July, T_2=30 July, T_3=15 August and T_4=30 August transplanting. Means followed by the same letter in a column did not differ significantly at the 5% level by LSD. NS=Not Significant.

CONCLUSIONS

In Bangladesh, ShB is a very notorious fungal disease for almost every season. Method for controlling the disease is an urgent need. The minimum RLH was observed in 30 July followed by 15 July transplanting and the maximum PDI in 30 August followed by 15 August transplanting for both the years. Moreover, the highest yield was recorded in 30 July and the lowest in 30 August transplanting during both the seasons. Finally, integrated disease management (IDM) packages need to be developed by using appropriate planting time, cultural practices and fungicides to control ShB disease of rice.

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Performance of Prilled Urea and Urea Super Granule by Applicators on Yield and Nitrogen Use Efficiency in Boro Rice

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ABSTRACT

A field experiment was conducted on validation of prilled urea (PU) and urea super granule (USG) applied by applicators on yield and nitrogen use efficiency during Boro 2014 season at Bangladesh Rice Research Institute (BRRI) farm, Gazipur (AEZ 28). Six treatment combinations of different N doses and methods of N application were tested to compare urea-N application by PU and USG applicator for rice yield, N uptake and N use efficiency over urea broadcasting. Application of N as PU or USG through applicator has same effect on grain yield, N uptake and N use efficiency compared with urea broadcasting. Statistically similar grain yield were observed with N application as PU or USG @ 78 kg N ha^{-1} by applicator which was comparable with urea broadcasting @ 135 kg N ha^{-1}. The N concentration and uptake in both panicle initiation (PI) and maturity stage were higher in USG deep placement than PU deep placement by applicators but the difference was not significant. Although agronomic use efficiency (AUE) of N was slightly higher in PU than USG applied by applicators but the recovery efficiency (RE) of N was higher in USG than PU.

Key words: PU, USG, deep placement, applicator, grain yield, AUE, RE.

INTRODUCTION

Nitrogen (N) fertilizer is a major essential plant nutrient and the most yield-limiting nutrient in rice (*Oryza sativa* L.) cropping systems worldwide (Yoseftabar, 2013, Ladha and Reddy 2003, Fageria *et al*., 2008). Especially in tropical Asian soils and almost every farmer has to apply the N fertilizer to get a desirable rice yield (Saleque *et al*., 2004). Judicious and proper use of N fertilizer can markedly increase the yield and improve the quality of rice (Chaturvedi, 2005). Both excess and insufficient supply of nitrogen is harmful to the rice crop and may decrease the grain yield. An adequate nitrogen supply can increase as much as 60% rice production over control (Mikkelsen *et al*., 1995).

Worldwide, N recovery efficiency for cereal production (rice, wheat, sorghum, millet, barley, corn, oat and rye) is approximately 33%. The unaccounted 67% represent a US$ 15.9 billion annual loss of N fertilizer (assuming fertilizer soil equilibrium) (Raun and Johnson, 1999). For lowland rice in the tropics recovery efficiency is 30-50% of applied N depending on season, yield level, the rate and timing of N application (Yoshida, 1981; De Datta, 1986). Low recovery of N fertilizer not only increases cost of production but also may contribute to ground water pollution (Fageria and Barbosa Filho, 2001). So, improved N fertilizer practices are needed to reduce environmental impacts and increase economic benefits of N fertilization.

The efficient use of N fertilizer is recognized as an important factor for rice cultivation, but it has always been a problem to raise the N utilization rate of the rice plants and to increase the efficiency of absorbed N for grain production irrespective of N amount being applied. Low N fertilizer use or recovery efficiency remains a problem in rice production in Asia (Hussain *et al*., 2000). The low efficiency of N fertilizers is

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mainly caused by losses of N from the soil-plant system. Low agronomic efficiency was caused by poor internal efficiency, rather than low supply of soil N or loss of fertilizer N. Thus often the application of large amount of N fertilizer by farmers to increase yield of HYV were not justified agronomically and ecologically (Hussain *et al*., 2005).

In Bangladesh, farmers use N fertilizer for rice cultivation as prilled urea broadcast or urea super granule (USG) deep placement. Broadcast applied nitrogen fertilizer being washed out of the paddies resulting in reduced nitrogen uptake and river pollution. One solution to this problem is to deep place urea fertilizers as urea granules (Alam *et al.,* 2014). Tarfa and Kiger (2013) reported that USG application with best practices increased N use efficiency by 40% and irrigated paddy yield increased up to 20-30% in Niger State, Nigeria. Likewise, Kuku *et al.* (2013) and Liverpool-Tasie and Kuku-Shittu (2015) maintained that UDP technology appreciably increased the yield of paddy in Niger State, Nigeria. In the same vein, Vargas (2012) established his study that utilization of UDP led to an increment in rice farmer in Lucia, Ecuador. Rahman and Barmon (2015) clearly established that the utilization of UDP technology significantly increased paddy grain yield in Bangladesh. It is proved that deep placement of USG reduces the N losses and increases the N use efficiency. But deep placement of prilled urea is a new concept to us. It may also reduce the N losses like USG or not. Recently BRRI has developed prilled urea and USG applicator. Therefore, in depth research will be needed to make a comparison study with prilled urea and USG applicators in terms of rice yield and economic benefit.

Considering the above circumstances, a field experiment was conducted to compare urea-N application by PU and USG applicator for rice yield and N uptake and to estimate the N use efficiency of PU and USG application by applicators.

MATERIALS AND METHODS

A field experiment was conducted in Boro 2014 season at the Bangladesh Rice Research Institute (BRRI) farm, Gazipur under the supervision of Soil Science Division in collaboration with Farm Machinery and Post Harvest Technology (FMPHT) Division. The soil of the experimental field was clay loam in texture having pH 6.5. The other nutrients status was as follows: organic carbon 1.18%, total N 0.16%, exchangeable K 0.17 meq/100g soil, available S 19 mg kg^{-1} and available Zn (DTPA extraction) 4 mg kg^{-1}. The experiment was laid out in a randomized complete block design with three replications. The individual plot size was 3.2 m × 12.8 m.

The treatment combinations were as follows:

T_1 = Control (no N fertilizer)

T_2 = Hand broadcasting of prilled urea (PU) @ 135 kg N ha^{-1} (Recommended dose)

T_3 = Hand broadcasting of prilled urea (PU) @ 78 kg N ha^{-1}

T_4 = PU application by applicator @ 78 kg N ha^{-1}

T_5 = USG application by applicator @ 78 kg Nha^{-1} (2.7 g/4 hills) (Recommended dose)

T_6 = Hand broadcasting PU @ 95 kg N ha^{-1} (70% of recommended dose of urea broadcasting)

Fertilizer was applied as basal @ 20-60-20-4 kg ha^{-1} of P, K, S and Zn from TSP, MP, gypsum and zinc sulphate respectively. For treatment T_2, T_3 and T_6 urea was applied in three equal splits; one third as basal, one third at active tillering stage and the rest one third at seven days before panicle initiation (PI) stage. In T_4 and T_5, the full dose of prilled urea and USG were applied at three days after transplanting by prilled urea and USG applicators.

Forty-five-day-old seedlings of BRRI dhan29 was transplanted on the last week of January. Irrigation, weeding and other cultural management practices were done equally as per needed. At PI stage, four hills from each plot was collected for counting tiller number, dry weight and nitrogen uptake. At maturity the crop was harvested manually in the 2nd week of May in the area of 5 m^2 at 15 cm above ground level for grain yield. However, 16 hills from each plot were harvested at the ground level for yield components and straw yield data. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis. The tiller and panicle number per meter square were also recorded. Nitrogen concentration and nitrogen uptake by grain and straw were determined by micro-Kjeldahl distillation method.

Nitrogen use efficiency was calculated using the following formulas (Fageria *et al.*, 1997):

Agronomic efficiency (AE) = $(G_f - G_u) / N_a$ = kg kg^{-1}

Where, G_f is the grain yield of the fertilized plot (kg), G_u is the grain yield of the unfertilized plot (kg), and N_a is the quantity of N applied (kg).

Recovery efficiency was calculated using the following formulas (FRG, 2012)

Recovery efficiency (RE) = $(NU_{NA} - NU_{NO}) / N_{RN}$

Where, NU_{NA} = Nutrient uptake (kg/ha) due to nutrient addition

NU_{NO} = Nutrient uptake (kg ha^{-1}) due to nutrient omission N_{RN} = Rate of nutrient addition (kg ha^{-1})

All the obtained data were analyzed statistically with the software CropStat 7.2 version.

RESULTS AND DISCUSSION

Dry matter yield and nitrogen uptake at panicle initiation stage

The tiller number and dry weight at panicle initiation (PI) stage were influenced significantly with application of N from different forms and methods in Boro season (Table 1). The highest tiller number per meter square was observed in T_2 treatment where PU was applied @ 135 kg N ha^{-1} as hand broadcasting followed by T_3 treatment where PU was applied @ 78 kg N ha^{-1} on hand broadcasting and the lowest in N control treatment. In comparison with N application by PU and USG applicator, no significant difference was observed for tiller production per meter square.

The highest dry weight production at PI stage was observed in T_2 treatment followed by T_6 and the lowest in N control. The T_3, T_4 and T_5 treatment produced statistically similar dry yield as they received same dose of N (78 kg ha^{-1}).

The N concentration was statistically similar in plant tissue at PI stage with application of N from different forms and different methods (Table 1). The highest N concentration in plant tissue was observed in T_2 treatment followed by T_6 treatment and the lowest was in N control treatment. The N application as USG by applicator gave better N concentration in plant tissue than N application as PU by applicator though the difference was statistically identical. A similar trend was observed for N uptake by all the N treatments at PI stage of Boro rice.

Grain and straw yield

The tiller and panicle number per meter square, grain and straw yield were significantly influenced by applying N from different forms and application methods in Boro rice of BRRI dhan29 (Table 2). The tiller number per m^2 in the control plot was only 189. With application of N from different forms and methods the tiller number per m^2 increased significantly over control. The highest tiller number was observed in T_2 treatment where PU was applied by hand broadcasting as recommended dose followed by T_6 and T_5. Significantly lower tiller number was obtained with N control. The other N treatment showed statistically similar result for tiller production. A similar trend observed for panicle production per m^2 in all N treatment in Boro season. The 1000 grain weight (TGW) was statistically similar for all N treatments including N control. But comparatively higher TGW was observed in USG deep placement (22.48 g) than PU deep placement (21.99 g) method (Table 2). Islam *et al.*, (2015) also found similar results where insignificant effect of urea applicator was on panicle intensity, panicle length and 1000-grain mass.

Table 1. Effect of PU and USG on growth, nitrogen concentration and uptake at PI stage of Boro rice, BRRI, Gazipur, 2014.

Treatment	Tiller no. m^{-2}	Dry wt. (t ha^{-1})	N (%)	N uptake (kg ha^{-1})
T_1 = N – control	182	1.26	1.38	17.59
T_2 = 135 kg N ha^{-1} (as PU by hand broadcasting)	419	3.54	1.75	63.63
T_3 = 78 kg N ha^{-1} (as PU by hand broadcasting)	371	2.88	1.51	43.37
T_4 = 78 kg N ha^{-1} (as PU by applicator)	318	2.52	1.45	36.41
T_5 = 78 kg N ha^{-1} (as USG by applicator)	338	2.76	1.65	45.81
T_6 = 95 kg N ha^{-1} (as PU by hand broadcasting)	345	3.19	1.70	55.10
CV (%)	*10.5*	*19.7*	*11.9*	*26.0*
LSD (0.05)	*63*	*0.97*	*0.34*	*20.52*

The grain yield of the N-control plot was only 3.05 t ha^{-1} and with receiving N from different sources and methods the grain yield increased significantly in all treatments over N-control (Table 2). The highest grain yield was observed in T_2 (5.56 t ha^{-1}) treatment where N was used @135 kg ha^{-1} as PU hand broadcasting followed by T_4 (5.35 t ha^{-1}) where N was used @78 kg ha^{-1} as PU by applicator. Similar grain yield was obtained with T_6 (5.35 t ha^{-1}) where N was used @ 95 kg ha^{-1} as PU hand broadcasting. Slightly lower grain yield was observed in T_5 treatment (5.21 t ha^{-1}) where N was applied @ 78 kg ha^{-1} as USG by applicator than T_4 (PU by applicator). But the difference was not statistically significant. Actually, all the N treatments produced statistically similar grain yield in Boro season. Islam *et al*., (2015) found that PU and USG applicators saved 29-32% of prilled urea without sacrificing grain yield in view of the nitrogen management options. Field trials conducted in farmers' fields across different agro-ecological zones (AEZ) showed that UDP with 25–35% less urea produced up to 20% higher yield compared to broadcast PU (Miah *et al.,* 2015; Gregory *et al.* 2010; IFDC 2013) which was dissimilar to this finding.

IFDC (2007) also reported that deep placement of N fertilizers had increased rice yield by 22% over broadcasting and decreased urea use by 47%. Kapoor *et al.* (2008) reported that significantly higher grain yield was observed with deep placement of NPK briquette compared to broadcast application. A similar trend was observed for straw yield although T_2 treatment gave significantly higher straw yield over some treatments may be due to higher N dose.

In this study, no significant yield differences were observed under N rates and application methods during the Boro season. Contrary to this study, Huda *et al*. (2016) who conducted an experiment and reported increased yield with increasing N rates from 78 to 156 kg N ha^{-1} during the Boro season, particularly in broadcast PU.

Table 2. Effect of PU and USG on yield and yield components of Boro rice, BRRI, Gazipur, 2014.

Treatment	Tiller no. m^{-2}	Panicle no. m^{-2}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1 = N – control	189	183	21.91	3.05	2.97
T_2 = 135 kg N ha^{-1} (as PU by hand broadcasting)	330	312	21.83	5.56	5.76
T_3 = 78 kg N ha^{-1} (as PU by hand broadcasting)	280	273	22.35	5.17	5.11
T_4 = 78 kg N ha^{-1} (as PU by applicator)	277	271	21.99	5.35	5.55
T_5 = 78 kg N ha^{-1} (as USG by applicator)	289	276	22.48	5.21	5.03
T_6 = 95 kg N ha^{-1} (as PU by hand broadcasting)	290	282	22.37	5.35	5.25
CV (%)	9.4	9.0	2.1	5.2	6.2
LSD (0.05)	46.92	43.36	NS	0.47	0.56

Nitrogen uptake

The grain and straw N concentrations and N uptake were significantly influenced by different doses and methods of N application (Table 3). The highest N concentration was observed in T_2 treatment followed by T_6 treatment. The N concentration in grain of USG treatment was higher than PU deep placement. A similar trend was observed for straw N concentration in all treatments.

The N uptake by grain and straw varied significantly with application of N in Boro season. The N uptake by grain in T_2 treatment was significantly higher than N-control, T_3, T_4 and T_5 treatment but T_6 treatment produced statistically similar N uptake like T_2. Mostly similar trend was observed for straw N uptake by rice at maturity stage.

The total nitrogen uptake (TNU) by rice at maturity stage showed significant variation with receiving different forms and method of N in Boro rice (Table 3). The highest Nitrogen uptake was obtained in T_2 treatment where recommended dose of N was applied and the lowest was found in control. The deep placement of PU and USG had no significant difference for N uptake in Boro rice of BRRI dhan29. Actually the crop slightly suffered in nitrogen deficiency at the PI stage particularly in the treatments of urea deep placement by applicators and the lower dose of N was applied.

Nitrogen use efficiency

Table 4 describes the agronomic use efficiency (AUE) and recovery efficiency (RE) of N. The AUE in the recommended dose of PU (135 kg N ha^{-1}) was 18.56 kg^{-1} and in 70% of recommended dose of PU (95 kg N ha^{-1}) it was 24.24 kg^{-1}. The deep placement of PU and USG increased the AUE of N. Significantly higher AUE were observed using 78 kg N/ha than 135 kg N ha^{-1}. The highest N use efficiency was observed in T_4 treatment (29.46 kg kg^{-1}) where PU was applied by applicator followed by T_5 treatment (27.68 kg kg^{-1}) where USG was applied by applicator but the difference was not significant.

Among the treatments, recovery efficiency (RE) of applied N varied from 40.21% to 50.40%. The highest RE of 50.40% was obtained in T_5 (78 kg N ha^{-1} by USG applicator) and the lowest in T_2 (135 kg N ha^{-1} by PU hand broadcasting) though the difference was statistically identical.

Deep placement of USG increased nitrogen use efficiency by keeping most of the urea nitrogen in the soil, close to plant roots and out of the irrigation water (IFDC, 2007). Kapoor *et al.,* (2008) also observed that significantly higher N uptake and N use efficiency with deep placement of N compared to broadcast application.

Table 3. Effect of PU and USG on N concentration and N uptake by Boro rice, BRRI, Gazipur, 2014.

Treatment	GN (%)	SN (%)	GNU (kg ha^{-1})	SNU (kg ha^{-1})	TNU (kg ha^{-1})
T_1 = N – control	0.87	0.49	26.66	14.43	41
T_2 = 135 kg N ha^{-1} (as PU by hand broadcasting)	1.08	0.61	60.24	35.13	95
T_3 = 78 kg N ha^{-1} (as PU by hand broadcasting)	0.95	0.54	49.23	27.62	77
T_4 = 78 kg N ha^{-1} (as PU by applicator)	0.89	0.51	47.88	27.99	76
T_5 = 78 kg N ha^{-1} (as USG by applicator)	1.00	0.56	52.25	28.16	80
T_6 = 95 kg N ha^{-1} (as PU by hand broadcasting)	1.05	0.59	56.08	30.58	87
CV (%)	5.2	9.5	6.9	10.4	6.0
LSD (0.05)	0.09	0.09	6.13	5.17	8.32

Table 4. Effect of PU and USG on agronomic use efficiency and recovery efficiency of N applied in Boro rice, BRRI, Gazipur, 2014.

Treatment	Agronomic use efficiency of N applied (kg^{-1})	Recovery efficiency of N applied (%)
T_1 = N – Control	-	-
T_2 = 135 kg N ha^{-1} (as PU by hand broadcasting)	18.56	40.21
T_3 = 78 kg N ha^{-1} (as PU by hand broadcasting)	27.17	45.84
T_4 = 78 kg N ha^{-1} (as PU by applicator)	29.46	44.59
T_5 = 78 kg N ha^{-1} (as USG by applicator)	27.68	50.40
T_6 = 95 kg N ha^{-1} (as PU by hand broadcasting)	24.24	47.97
CV (%)	13.6	13.10
LSD (0.05)	6.49	11.33

CONCLUSIONS

The recommended dose of urea by hand broadcasting @135 kg N ha^{-1} produced the highest yield but the yield was statistically similar to the application of N as PU or USG @ 78 kg ha^{-1} by applicators. However, it would save around 57 kg N ha^{-1} as well as protect the soil from environmental pollution. Moreover, AUE and RE of N were found highest with the application of N as PU or USG by applicators than that of recommended dose of urea.

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Integrated Effects of Poultry Manure and Chemical Fertilizer on Yield, Nutrient Balance and Economics of Wetland Rice Culture

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ABSTRACT

Field trials were conducted for two years to evaluate the integrated effect of poultry manure (PM) and chemical fertilizers on yield, nutrient balance and economics of rice at BRRI, Gazipur (AEZ-28 and land type- High Land) during Boro 2009 to T. Aman 2010. Eight treatment combinations, where PM @ 1, 2, 3 t ha^{-1} with IPNS (Integrated plant nutrient system) based dose and PM @ 1, 2, 3 t ha^{-1} with 50% STB (soil test based) dose along with a control and 100% STB chemical fertilizer were tested. Immediate effects of manure and fertilizer were evaluated in Boro season and residual effects were observed in the following T. Aman season. Application of PM @ 2 t ha^{-1} with IPNS based chemical fertilizer or PM @ 3 t ha^{-1} with 50% STB dose gave higher grain yield in Boro season. Some residual effects in the succeeding T. Aman rice were observed where PM was used @ 3 t ha^{-1}. The highest net return was obtained with 3 t PM ha^{-1} with 50% STB dose. A positive nutrient balance of phosphorus and sulfur were observed in PM and chemical fertilizer treated plots.

Key words: Poultry manure, IPNS, grain yield, nutrient balance, economics

INTRODUCTION

Poultry manure is an excellent, low cost fertilizer and is a valuable organic source of essential plant nutrients and soil amendments to improve soil quality. It contains both organic and inorganic forms of nutrients. Poultry manure (fresh or semi-decomposed) is a good source of macro and micronutrients for plants as well as a potential source of organic matter in soil (Saha *et al.,* 2004). At present about 2 million ton poultry manure per year is produced in Bangladesh which can supply about 3 kg P/ha/yr (Rijpma and Jahiruddin, 2004) and application of 2 ton poultry manure ha^{-1} may replace the full dose of P and S and 60% N and K fertilizer requirement for target yield of 5-6 t ha^{-1} rice (Miah *et al.,* 2006). When organic manure was applied in conjunction with inorganic fertilizers for efficient growth for crop, declination of organic carbon was arrested (Singh *et al*., 2001).

Around 30 days decomposed poultry manure with 50% STB chemical fertilizer is good in terms of nutrients and grain yield of rice as well as soil health (Hossain *et al*., 2010). Long term fertilizer experiments involving intensive cereal based cropping systems reveal a declining trend in productivity even with the application of recommended levels of N, P and K fertilizer (Mahajan *et al*., 2002; Mahajan and Sharma, 2005). Without adequate and balanced use of chemical fertilizers and with little or no manure have caused severe fertility deterioration.

Combined use of chemical and organic fertilizer increases retentions and improves nutrient availability. High analysis fertilizers have low contents of micronutrients, but combined use with organic manure makes these nutrients available to plants. Fixation of P could be reduced and effectiveness of K can be increased when chemical fertilizer is combined with organic manures. All crops can be benefited from poultry litter but it should not be applied to soil beyond the limits of the growing crops nutrient needs. This will ensure efficient use of manure nutrients and minimize

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nutrient leaching or run off into the surface and ground water system. Fertilizer recommendations based on soil test results are the only reliable way to determine the crop requirement. Soil testing, manure analysis and proper estimation of yield goal are necessary to calculate proper agronomic application rates of manure.

Now it is the demand of the time to develop an integrated organic and inorganic source of nutrients for sustainable agriculture that can ensure food production with high quality and maintain soil fertility. Integrated Nutrient Management (INM) is a concept of addition of organic manure with chemical fertilizer. Integrated Plant Nutrient Systems (IPNS) is a process where total nutrient adjusted from organic and inorganic fertilizer sources to obtained maximum yield with a view to total improvement of soil health. Combined use of organic manure and chemical fertilizer results in higher return to investment and better cost-benefit ratio (Rahman *et al.,* 2009). The integrated use of poultry manure and chemical fertilizer may increase the productivity and reduce the chemical fertilizer dose in Rice-Rice cropping pattern. So, this study was undertaken to determine the doses of poultry manure with chemical fertilizers on the basis of IPNS concept and also determine the level of poultry manure addition with 50% soil test based chemical fertilizer dose.

MATERIALS AND METHODS

Field experiments were conducted for two years at BRRI experimental farm, Gazipur during Boro 2009 to T. Aman 2010 seasons. The soil of the experimental field was clay loam in texture having pH 6.84, organic matter 2.42%, total N 0.14%, available P 5.77 mg kg^{-1}, exchangeable K 0.14 meq 100 g^{-1} soil, available S 6.6 mg kg^{-1} and available Zn 2.8 mg kg^{-1}. Eight following treatments viz T_1 = Absolute control (native nutrients), T_2 = PM @ 1 t ha^{-1} + IPNS based STB dose, T_3 = PM @ 2 t ha^{-1} + IPNS based STB dose, T_4 = PM @ 3 t ha^{-1} + IPNS based STB dose, T_5 = PM @ 1 t ha^{-1} + 50% STB dose, T_6 = PM @ 2 t ha^{-1} + 50% STB dose, T_7 = PM @ 3 t ha^{-1} + 50% STB dose and T_8= 100% STB dose were tested in the experiment. Thirty days semi-decomposed PM (oven dry based), one-third of N and the whole amount of PKS were applied at final land preparation as per treatment requirement in Boro season. The remaining two-third N was applied in two equal installments at 25-30 days after transplanting and at seven days before panicle initiation stage. In T. Aman, the residual effect of PM was observed and the treatment combinations were; T_1 = Absolute control, T_2 = Residual effect of PM @ 1 t ha^{-1} + 100% STB dose, T_3 = Residual effect of PM @ 2 t ha^{-1} +100% STB dose, T_4 = Residual effect of PM @ 3 t ha^{-1} + 100% STB dose, T_5 = Residual effect of PM @ 1 t ha^{-1} + 50% STB dose, T_6 = Residual effect of PM @ 2 t ha^{-1} + 50% STB dose, T_7 = Residual effect of PM @ 3 t ha^{-1} + 50% STB dose and T_8= 100% STB dose. The time and method of chemical fertilizer application was same as Boro rice. In Boro season 40-day-old seedlings of BRRI dhan29 and in T. Aman 30-day-old seedlings of BRRI dhan31 were transplanted. The design of the experiment was RCBD with three replications. The individual plot size was 4 m × 4 m. The crops were harvested at maturity from 5 m^2 areas at the centre of each plot and then grain yields were recorded at 14% moisture and straw yields at oven dry basis.

Poultry manures samples as well as rice grain and straw samples of Boro and T. Aman rice were analyzed for the determination of N, P, K and S in the Soil Science Division laboratory, BRRI, Gazipur. For analyzing the P, K and S content, samples were digested with di-acid mixture of nitric and perchlororic acid at the ratio 5:2 following the method described by Yoshida *et al*. (1976) and N by Micro-Kjeldahl distillation method (Yoshida, *et* *al.*, 1976). After two years, surface (0-15 cm depth) soil samples were collected and analyzed for chemical properties like organic carbon, total nitrogen, available phosphorus, exchangeable potassium, available sulfur and zinc following standard procedure. All the data were analyzed statistically with the software of Crop Stat 7.2 version.

RESULTS AND DISCUSSION

Grain and straw yield

Poultry manure application either with IPNS or STB base chemical fertilizer had positive influence on the grain yield of Boro rice (Table 1). In Boro 2009 significantly higher grain yield was obtained when poultry manure was applied @ 2 t ha^{-1} with adjusted IPNS based chemical fertilizer (T_3) and PM @ 3 t ha^{-1} + 50% STB dose (T_7) compared to 100% STB (T_8) chemical fertilizer but in 2010, the result was insignificant. The mean grain yield (average of two years) was 6.20 t ha^{-1} when poultry litter @ 2 t ha^{-1} with adjusted IPNS based fertilizer and PM @ 3 t ha^{-1} + 50% STB dose while 100% STB treatment produced the yield 5.87 t ha^{-1}. About 0.3 t ha^{-1} higher average grain yield was obtained from poultry litter treated plot compared to 100% STB dose.

Both the treatments produced statistically similar yield to each other may be due to addition of similar amount of nutrients in the soil. The lowest yield was obtained from control treatment. Lidong *et al.* (2009) also reported significant positive effects of organic amendments on rice yield.

In T. Aman 2009, some residual effect of PM for grain yield (which was applied in Boro season) was observed (Table 1). A significant amount of residual effect of PM was observed in T_5, T_6 and T_7 treatments where 1, 2 and 3 t ha^{-1} PM with 50% chemical fertilizer was applied respectively, in the previous Boro crop but in T. Aman 2010, the residual effect was insignificant. The two years average yield from 100% NPKS was lower than those treatments where PM was applied more than 1 t ha^{-1}. This result confirmed the data obtained by other experiments conducted by Soil Science Division, BRRI (Miah, 2006) and Hossain *et al.* (2010). Similar trend was also observed in case of straw yield production in both the years and seasons (Table 2).

Table 1. Immediate and residual effects of poultry manure and chemical fertilizer on the grain yield (t ha^{-1}) of rice in Boro-Fallow-T. Aman cropping pattern at BRRI, Gazipur, 2009-10.

Treatment	Immediate effect (Boro grain yield)			Residual effect (T. Aman grain yield)		
	2009	2010	Mean	2009	2010	Mean
T1	2.53	2.86	2.70	2.71	2.54	2.63
T2	5.75	5.84	5.80	3.02	3.49	3.26
T3	6.24	6.15	6.20	3.17	3.56	3.37
T4	5.86	5.98	5.92	3.33	3.73	3.53
T5	5.36	5.72	5.54	3.34	3.36	3.35
T6	5.84	5.94	5.89	3.43	3.38	3.41
T7	6.14	6.25	6.20	3.46	3.48	3.47
T8	5.68	6.05	5.87	3.06	3.51	3.29
LSD (0.05)	0.19	0.23		0.27	0.21	
CV (%)	1.62	1.55		2.31	2.16	

Table 2. Immediate and residual effects of poultry manure and chemical fertilizer on the straw yield (t ha^{-1}) of rice in Boro-Fallow-T. Aman cropping pattern at BRRI, Gazipur, 2009-10.

Treatment	Immediate effect (Boro grain yield)			Residual effect (T. Aman grain yield)		
	2009	2010	Mean	2009	2010	Mean
T1	2.77	3.19	2.98	3.17	3.33	3.25
T2	6.17	6.34	6.26	3.65	6.10	4.88
T3	6.54	6.60	6.57	4.47	6.18	5.33
T4	6.65	6.34	6.50	4.62	6.24	5.43
T5	5.68	6.22	5.95	3.78	5.33	4.56
T6	6.23	6.37	6.30	3.99	5.64	4.82
T7	6.67	6.70	6.69	4.01	5.83	4.92
T8	5.93	6.52	6.23	4.03	6.27	5.15
LSD (0.05)	0.16	0.18		0.62	0.38	
CV (%)	2.54	2.35		2.75	2.62	

Nutrient uptake of rice

There is wide variation in nutrient uptake influenced by different rates of poultry manure with chemical fertilizer (Table 3). The highest N and P uptake was observed in T_4 treatment where PM was applied @ 3 t ha^{-1} with IPNS based inorganic fertilizers followed by treatment T_7 where PM was applied @ 3 t ha^{-1} with 50% STB dose. The present observation was similar with the earlier findings (Rahman *et al.*, 2009). The reasons may be the higher nutrient concentration in poultry manure (Saha *et al.*, 2004) and literatures suggest that poultry manure is a good source of P (Griffin *et al.*, 2003). Similar trend was also observed in case of other nutrients (K and S) uptake by rice in both years.

Apparent nutrient balance

Apparent nutrient balance as influenced by different rates of poultry litter with chemical fertilizer was studied. In calculating apparent nutrient balance it is assumed that 30 kg N from irrigation water and 20 kg N from BNF (Biological nitrogen fixation) was considered. Assuming that Boro rice crop requires 100 cm water ha^{-1}, thus the amount of P and K through irrigation water was 0.6 kg and 14 kg ha^{-1} respectively.

It was observed that the apparent nutrient balance in the control plot was always negative for all the treatments since no fertilizer or PM was added to the plots. Nitrogen replenishment through different rates of poultry manure with chemical fertilizer was not enough to balance N removal by crops since much of the applied N was lost from the soil (Fig. 1). Phosphorous balance was positive in all poultry manure treated plots irrespective of chemical source. These results were similar with the findings of some earlier works (Hossain *et al.,* 2010 ; Ali *et al.,* 2009).

Table 3. Nitrogen, phosphorous, potassium and sulphur uptake by rice as influenced by poultry manure, T. Aman.

Treat.	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})			S uptake (kg/ha)		
	2009	2010	Total	2009	2010	Total	2009	2010	Total	2009	2010	Total
T_1	50	49	99	9	12	21	49	44	93	7	44	51
T_2	70	84	154	12	18	30	60	78	84	9	80	89
T_3	87	90	177	14	18	32	72	82	154	10	82	92
T_4	93	96	189	15	18	33	75	91	166	11	92	103
T_5	67	76	143	12	15	27	61	81	142	8	82	90
T_6	81	85	166	12	16	28	66	83	149	9	84	93
T_7	84	93	177	13	17	30	69	79	148	9	77	86
T_8	81	89	170	12	14	26	66	77	143	8	77	85
LSD (0.05)	11.29	10.28		1.35	1.87		10.07	12.33		1.0	11.82	

Phosphorous balance was higher where poultry litter was applied at 3 t ha^{-1} basis either with STB or IPNS based compared to sole applied chemical fertilizer. But in case of K, it was evident that K uptake by the crop is far exceeded than that was replenished from fertilization. Sulphur also showed a positive nutrient balance in all poultry manure applied treatments which are in agreement with the findings of Haque *et al*. (2001).

Economic analysis

The application of poultry manure either with IPNS or 50% STB based chemical fertilizer increased gross and net return than sole application of STB chemical fertilizer (Table 4). The highest gross and net return was obtained in the treatment T_7 where PM was applied @ 3 t ha^{-1} with 50% STB chemical fertilizer followed by the treatment T_3 and T_4 where PM was applied @ 2 and 3 t ha^{-1} with IPNS based chemical fertilizer respectively (Table 4). Among the PM treatment the lowest net return was obtained from PM 1 t ha^{-1} with IPNS based chemical fertilizer. But the MBCR was highest (4.82) in the treatment T_4 where 3 t ha^{-1} PM plus IPNS based chemical fertilizer were applied followed by T_3 i.e. PM 2 t ha^{-1} with IPNS based chemical fertilizer (4.71). Almost similar result was found by Rahman *et al.*, (2009).

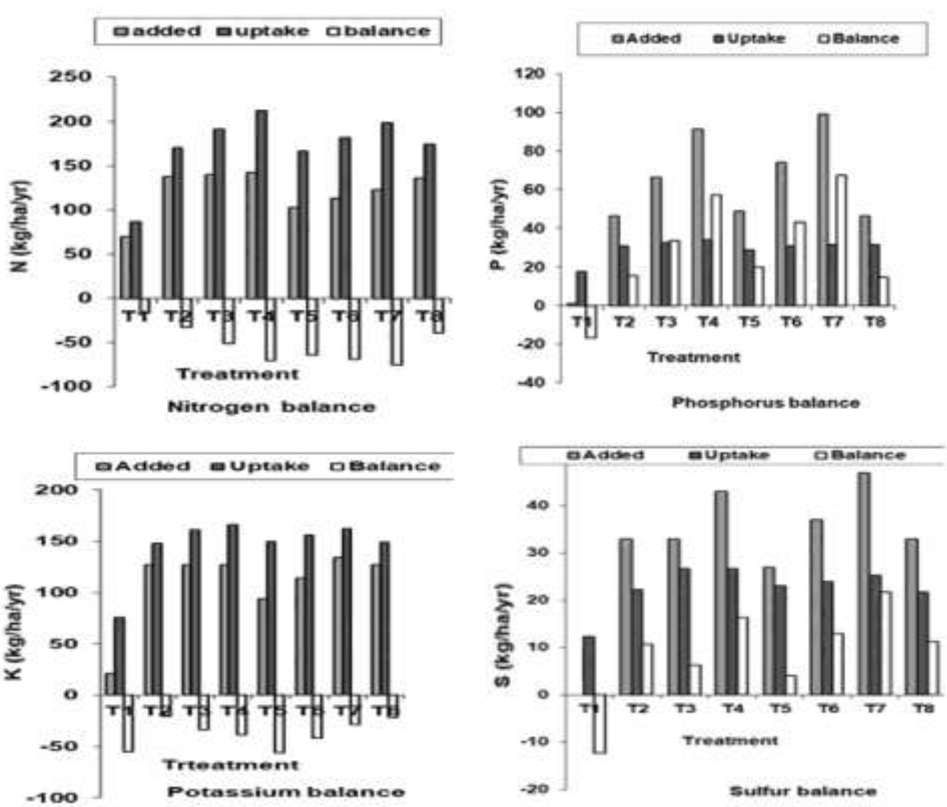

Fig. 1. Integrated use of poultry manure and chemical fertilizers on the apparent nutrient balance of rice. BRRI, Gazipur, 2009-10 (Average of two years).

Table 4. Integrated use of poultry manure and chemical fertilizers on marginal benefit-cost ratio of rice. BRRI, Gazipur 2009-10 (Average of two years).

Treatment	Yield (t ha^{-1})		TVC (Tk ha^{-1})	Return (Tk ha^{-1})			MBCR
	GY	SY		Gross	Added	Net	
T_1	5.33	6.23	0	92410	-	92410	-
T_2	9.06	11.14	18003	158180	65770	140177	3.65
T_3	9.57	11.90	15919	167350	74940	151431	4.71
T_4	9.45	11.93	15193	165610	73200	150417	4.82
T_5	8.89	10.51	14132	154370	61960	140238	4.38
T_6	9.30	11.12	15405	161740	69330	146335	4.50
T_7	9.67	11.61	16666	168270	75860	151604	4.55
T_8	9.16	11.38	24711	160160	67750	135449	2.74

Note: Price: Rice grain= Tk 15 kg^{-1} and Rice straw= Tk 1.5 kg^{-1}, Cost of poultry litter 1000 Tk t^{-1}. Chemical fertilizer applied as Urea, TSP, MP and Gypsum. Fertilizer cost: Urea= Tk 10.00 kg^{-1}, TSP= Tk 40.00 kg^{-1}, MP= Tk 35.00 kg^{-1}, Gypsum= Tk 7.00 kg^{-1}. Labour wage= Tk 150 day^{-1}, 3 man days ha^{-1} for fertilizer and manure application and 2 man days ha^{-1} for per ton additional products including by products.

Nutrient status of the post-harvest soil

Different nutrients in the post-harvest soil increased slightly with the application of PM in the experimental plots. Irrespective of rate of poultry manure, the percent organic carbon and nitrogen were increased insignificantly in the plots compared to control plot (Table 5). Zaman *et al.*, (2002) reported that the organic matter and residual N remaining in the soil was greater with poultry manure than with chemical fertilizer. The soil available P was increased significantly after application of 3 t ha^{-1} PM in the soil over control. Hossain *et al.*, (2010) found that nitrogen based manure or compost application resulted in available soil P levels that were significantly greater than those for the P-based manure or compost application. Similar trend was also obtained in case of other available nutrients in the post harvest soil.

Table 5. Nutrient status of the post-harvest soil influenced by poultry manure with chemical fertilizer.

Treatment	OC (%)	Total N (%)	Available P (ppm)	Exch. K (meq/100g soil)
T_1	1.49	0.14	5.91	0.24
T_2	1.63	0.16	7.67	0.25
T_3	1.64	0.16	10.08	0.25
T_4	1.69	0.17	11.33	0.25
T_5	1.57	0.15	6.68	0.25
T_6	1.62	0.16	7.67	0.26
T_7	1.68	0.16	10.67	0.25
T_8	1.52	0.15	6.18	0.25
LSD (0.05)	0.039	0.010	1.23	0.029
Initial soil nutrients	1.40	0.14	5.77	0.14

CONCLUSION

From the above findings it appears that PM @ 2 t ha^{-1} with IPNS based chemical fertilizer dose or PM @ 3 t ha^{-1} with 50% chemical fertilizer dose may be the suitable combination for obtaining higher grain yield of BRRI dhan29 in wetland Boro rice culture. Some residual effect of PM was also observed in the succeeding T. Aman rice. A positive nutrient balance of P and S was observed in the combined use of poultry manure and chemical fertilizer treated plots but other nutrients like N and K remained in negative balance.

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Variability Assessment of Different Maintainer Lines for Hybrid Rice Development Based on Qualitative Traits

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ABSTRACT

The assessment of genetic diversity among nineteen maintainer lines was studied based on thirteen qualitative traits. The single linkage clustering, morphological dendogram were performed to assess the traits. Most of the traits showed variation in different maintainer lines except auricle colour. On the basis of flag leaf attitude, a maximum four groups were formed with erect, semi-erect, horizontal and descending type leaf angle. The maintainer line BRRI20B has awn tip, which is unique from the rest of the studied maintainer lines. Nineteen maintainer lines were grouped into four different clusters and a considerable level of variability was displayed for most of the traits examined. The clustering pattern revealed, cluster I was the largest and consisted seven maintainer lines. Among them maintainer lines BRRI52B and BRRI60B were the most closely associated. Cluster II represent diverse sources materials and its revealed non-correspondence of geographic diversity with genetic divergence. Thus the cluster analysis has revealed the genetic variation and the traits contributing for the variation. Hence, this maintainer lines can be utilized for trait improvement in breeding programmes for the traits contributing for major variation.

Key words: Maintainer line, genetic variability, qualitative traits

INTRODUCTION

Rice (*Oryza sativa* L.) is considered as one of the most important cereal crops and the staple food for more than half of the world's population (Jiang *et al.,* 2013).Rice production area of Bangladesh is about 10 million hectares of land in which the area planted to hybrid rice was around 0.7 Mha, which contributed 3-4 MT of additional rice to the total rice production in the country (AIS, 2018). Although Bangladesh is self-sufficient in cereal production, there is a great challenge of rapid growth of the population, decreasing arable land, reducing productivity and global climate change. We need to increase the production vertically to meet up the food demand of growing population and need to produce more rice per unit area. Hence hybrid rice technology has proved to be one of the most feasible and readily adoptable approaches as they yield about 15-20 percent more than the best of the improved or high yielding varieties (Virmani, 1994). The performance and heterosis of hybrids are associated with genetic divergence between their parental lines. Selection of suitable parental lines like cytoplasmic male sterile line (CMS), maintainer line and restorer lines to develop heterotic combinations can be facilitated by determining genetic divergence among them. Due to the importance of rice as one of the major world food crops, its genetic diversity has created great interest of researchers. Genetic diversity in the available gene pool is the foundation or the raw material of all plant improvement programmes. Several genetic diversity studies have been successfully

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utilized in different crop species based on quantitative and qualitative traits in order to select genetically distant parents for hybridization (Islam *et al*., 2018; Bedoya *et al*., 2017; Ahmed *et al*., 2016; Islam *et al*., 2016). The precise assessment of variability within the parental lines is necessary not only for better understanding of the differentiation pattern but also to assist in selecting appropriate materials to broaden the genetic base and the genetic improvement of cultivars. Careful selection of parental lines on the basis of their genetic diversity may lead to the development of hybrids with higher yield potential than parents and standard check varieties (Julfiquar *et al.,* 1985).

The majority of programmes involved in the improvement of rice productivity mainly focused on the yield aspects. On the other hand, quantitative traits and other important qualitative characters have been neglected. Morphological characterization using qualitative traits is a preliminary step to estimate the variability and relationship among cultivars. Qualitative characters are important for plant descriptions (Kurlovich, 1998) and are influenced by consumer preference, socio-economic scenario and natural selection (Hien *et al.,* 2007). Incase of hybrid rice, so far very limited work has been done on diversity of parental lines using quantitative characters but no work has been accomplished on diversity of parental lines using agronomic qualitative traits. Hence, keeping the importance of hybrid rice and scant literature on these aspects, the present investigation was undertaken as a first attempt with the objective of variability assessment of different maintainer lines for hybrid rice development based on qualitative traits.

MATERIALS AND METHODS

Present investigations were conducted at the Bangladesh Rice Research Institute (BRRI) farm, Gazipur. Nineteen maintainer lines were characterized for 13 qualitative traits. Among them 17 maintainer lines were developed locally and two of them namely IR78355 IR75595 originated from International Rice Research Institute (IRRI) (Table 1). The experiment was laid out in a randomized complete block design (RCBD) with three replications during T. Aman season 2015. The BRRI developed maintainer lines were BRRI19B, BRRI20B, BRRI22B, BRRI25B, BRRI42B, BRRI52B, BRRI55B, BRRI60B, BRRI63B, BRRI67B, BRRI69B, BRRI70B, BRRI71B, BRRI73B, BRRI76B, BRRI79B, BRRI81B. The maintainer lines originated from IRRI were IR75595B, IR78355B. Twenty-one-day old seedlings were transplanted at the rate of one seedling per hill with plant to plant distance of 15 cm and row to row distance of 20 cm. The standard cultivation practices prescribed for hybrid rice were followed precisely. Observations on maintainer lines were recorded for 13qualitative traits viz ligule colour, ligule shape, auricle colour, collar colour, blade colour, blade pubescence, basal leaf sheath colour, susceptibility to BLB, angle of flag leaf, stigma colour, awn: distribution, panicle exsertion, and seedcoat colour. The phenotypically distinguishable qualitative traits are used as a preliminary tool for assessing genetic variability.

These characters were scored based on 'Descriptors for cultivated rice (*Oryza sativa* L.)' developed by GRSD, BRRI (2018). Ten random plants from each entry were selected for recording observations. Frequency distributions for all of the qualitative traits were computed. Cluster analysis was done to group the genotypes into a dendogram by using PAST software.

Table 1. Composition of clusters based on similarity co-efficient for thirteen qualitative characters in nineteen maintainer lines.

Cluster	No. of maintainer lines	Maintainer line	Frequency (%)
I	7	BRRI52B, BRRI60B BRRI63B, RRI76B, BRRI67B, RRI81B, BRRI25B	36.84
II	5	BRRI71B, IR78355B, IR75595B, BRRI73B, BRRI79B	26.32
III	4	BRRI55B, BRRI69B, BRRI22B, BRRI70B	21.05
IV	3	BRRI42B, BRRI19B, BRRI20B	15.79

RESULTS AND DISCUSSION

Qualitative characters are important for plant description (Kurlovich, 1998) and mainly influenced by the consumers preference, socio-economic scenario and natural selection (Das and Ghosh, 2011). These qualitative characters are less influenced by the various environmental conditions. The present study exhibits considerable level of variability in most of the observed qualitative traits except auricle colour. Figure 1 shows the graphical representation of frequency distribution for 13 qualitative traits. The majority of the maintainer lines were characterized by white ligule colour (89.47%), 2-cleft ligule shape (63.15%). Again most of the maintainer lines showed pale green collar colour (57.89%), green blade colour (47.36%), intermediate blade pubescence (63.15%), green basal leaf sheath colour (73.68%), very low susceptibility to BLB (84.21%), semi-erect angle of flag leaf (68.42%) and white stigma colour (89.47%). Panicle exertion included well exserted (52.63%), moderately exerted (31.57%), and just exserted (15.74%). On the basis of awning character, most of the maintainer lines were found to be awn less (94.73%), only one maintainer line BRRI20B showed awn tip only (5.26%). This type of unique character could be efficiently used in identification and protection from biopiracy. Among the 19 maintainer lines most of the lines showed light brown seedcoat colour (68.42%) followed by brown seedcoat colour (31.57%). Similar findins were reported by Akter *et al.*, (2017), Moukoumbi *et al.*, (2011), Ahmed *et al.*,(2015), Parikh *et al.*, (2012), Singh and Mishra., (2013), Pragnya *et al.*, (2018) and Shamim, M Z and Sharma, V K (2014).

However, Parikh et al., (2012) observed green basal leaf sheath colour (84.5%), white ligule colour (94.7%). M Z Islam (2017) and Pragnya *et al.*, (2018) found 2-cleft shaped ligule in all jhum rice from hilly areas landraces and soft rice genotypes respectively. Monika *et al.*, (2007) and Bora *et al.*, (2008) used the same traits to characterize nineteen and eleven cultivars of rice respectively. Ahmed *et al.* (2015) also reported that majority of the genotypes possess green blade colour (47%) and white colour of stigma (90%). Singh and Mishra (2013) reported pubescence of blade surface (57%), semi erect flag leaf attitude (75%), awns absent (91%), well exserted panicle (57%). Pragnya *et al.*, (2018) also found semi-erect flag leaf attitude in 14 soft rice genotypes. Shamim and Sharma (2014) found light brown seedcoat colour (38.8%) among different rice varieties for qualitative traits.

Fig. 1. Morphological variations and frequency distribution for13 qualitative traits of 19 maintainer lines.

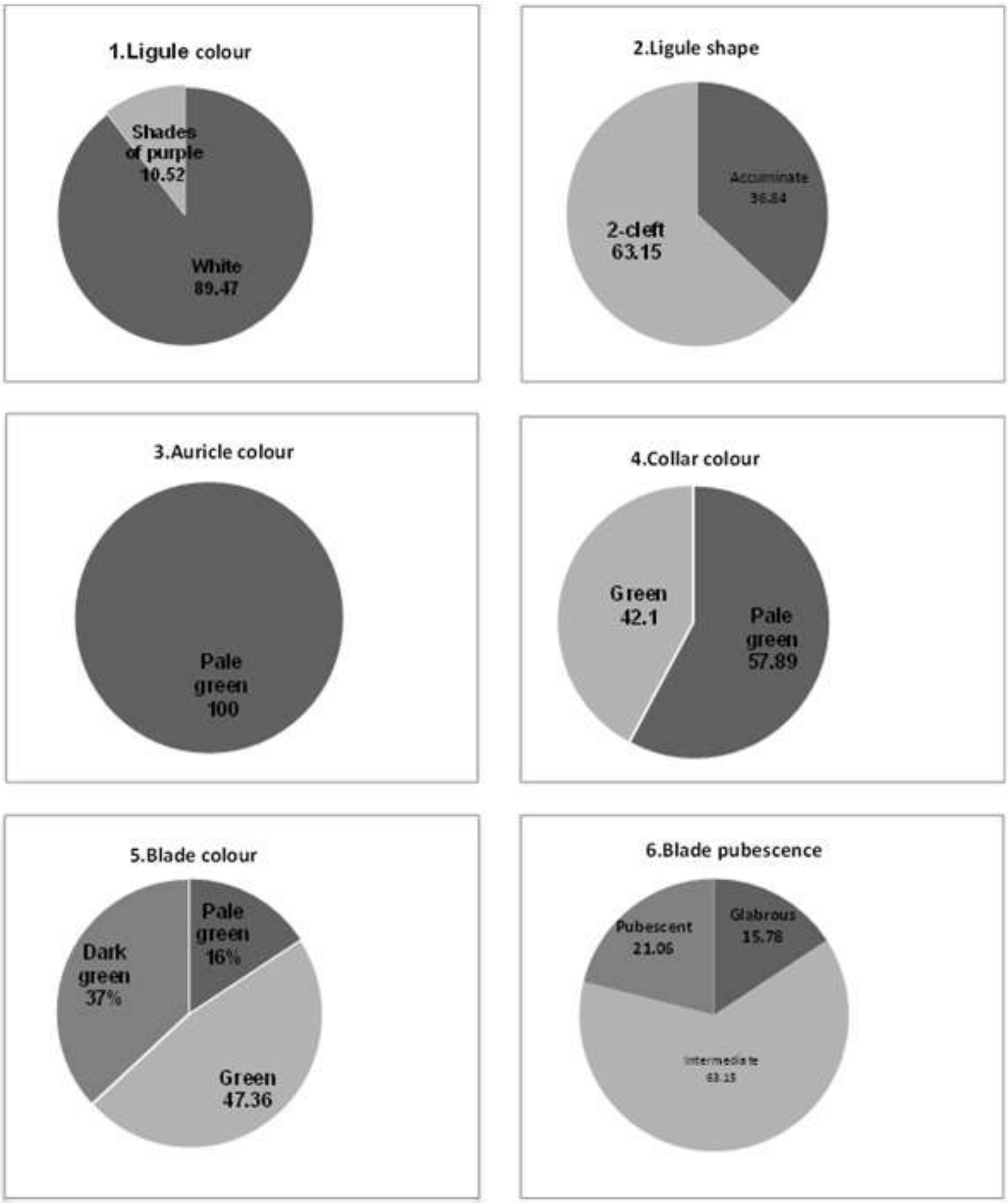
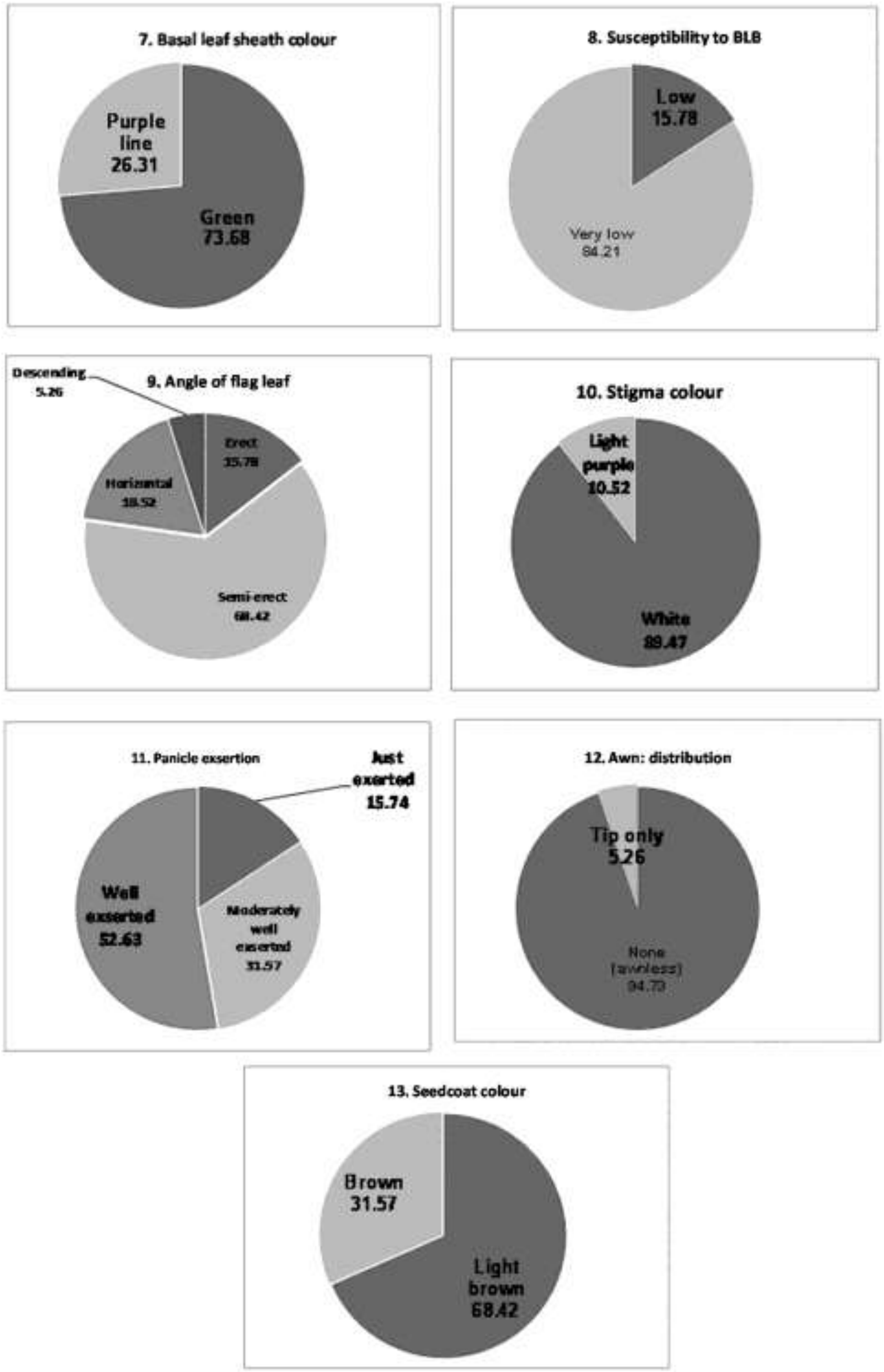


Fig. 1. Continued.



All the maintainer lines were grouped into four major clusters at 0.25 minimum distance between clusters and its frequency distribution (Fig. 2). The value of 0.25 was fixed only for the convenience of explanation under this study. Cluster I contained maximum seven entries followed by five in cluster II, four in cluster III and three in cluster IV. Thus cluster I, cluster III and IV represented only BRRI developed maintainer lines but cluster II represented the both BRRI and IRRI developed maintainer lines. The genotypes from the same geographical origin mostly grouped together; however, the less frequent genotypes from different origins also grouped within the same cluster. Maintainer lines BRRI52B and BRRI60B grouped into same cluster at minimum distance within clusters.

Therefore, these two maintainer lines can be considered as morphologically closest and might possess same genetic background. According to Ali *et al.,* (2000) cluster analysis has the singular efficacy and ability to identify crop accessions with the highest level of similarity. Even though the dendogram also proved the above statement in terms of similarity existing among the tested maintainer lines,a wide variability among them was identified. Suriyagoda *et al.,* (2011) have reported a similar variability of rice varieties.

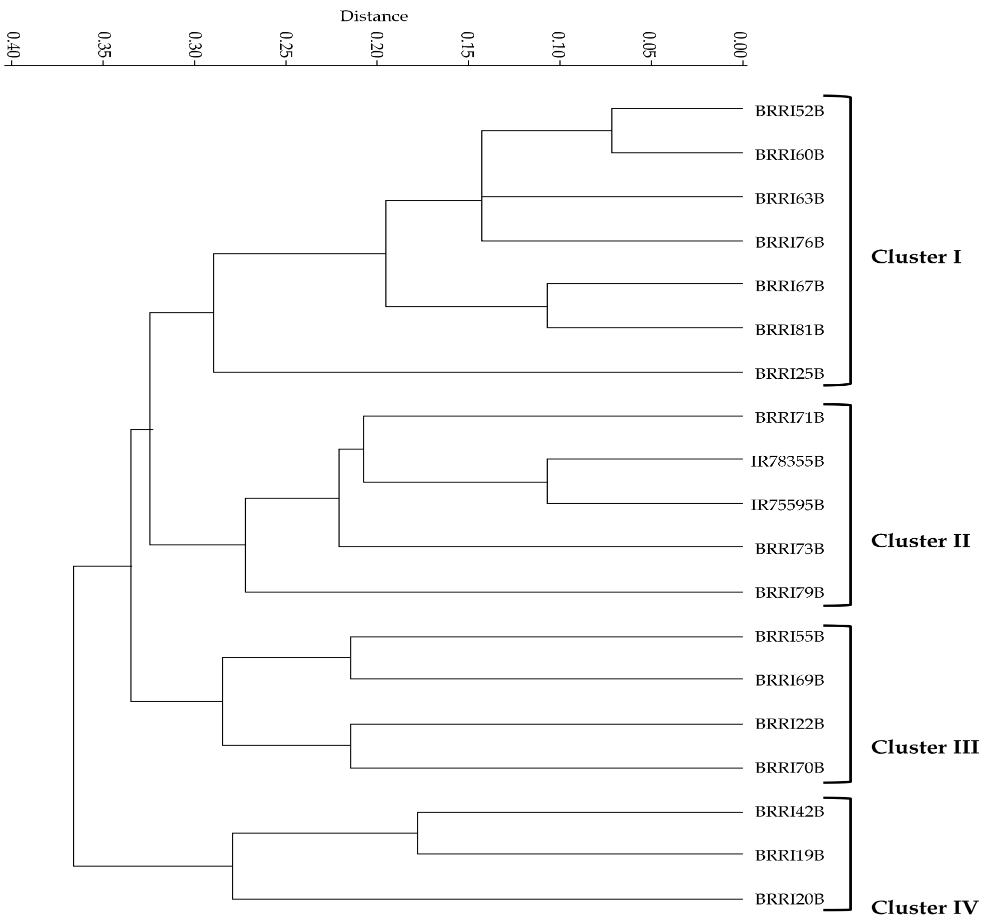


Fig. 2. Dendogram of 19 maintainer lines of hybrid rice obtained through single linkage cluster analysis.

As per the scattered diagram (Fig. 3), the maintainer lines were apparently distributed into four clusters. The results indicated that the maintainer linesthat were placed far away from the centroid were more genetically diverse, while the genotypes that were placed near the centroid possessed more or less similar genetic background. Similar findings were also reported by other authors (Siddique *et al*., 2016a, 2016b).

However, the selection of parents for hybridization from different clusters may provide more variability and high heterotic effect. Similar finding was also reported by Pradhan and Roy (1990). Similarly, the tested qualitative traits can be utilized to broaden the genetic base and for the improvement of parental lines. Further, Tehrim *et al*., (2012) also proved that agro-morphological traits can be used effectively to characterize the rice cultivars.

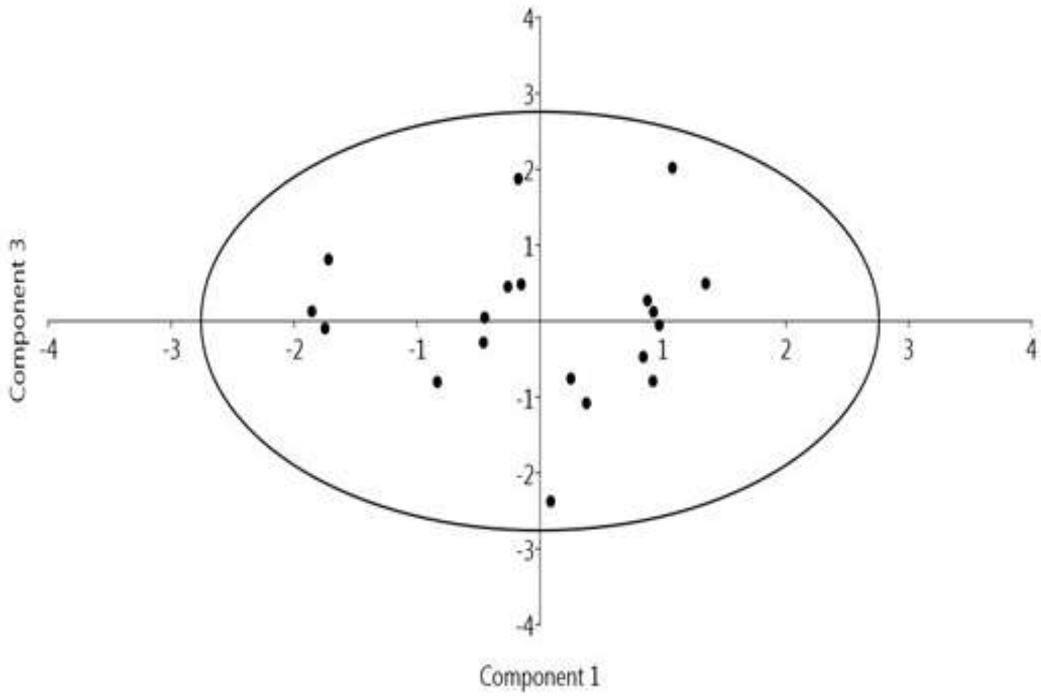


Fig. 3. Scatter diagram of 19 maintainer lines based on their qualitative traits.

CONCLUSION

The present study shows a considerable level of variability among the studied maintainer lines. It interprets a considerable amount of morphological variation along with the qualitative traits of maintainer lines. The results show that cluster I, cluster III and IV represented only BRRI developed maintainer lines but cluster II represented both BRRI and IRRI developed maintainer lines. The genotypes from the same geographical origin mostly grouped together; however, the less frequent genotypes from different origins also grouped within the same cluster. The selection of parents for hybridization from different clusters will provide more variability and high heterotic effect. Among the 13 traits, panicle exsertion and flag leaf angle are considered as important traits for hybrid rice development and selection could be done considering these traits.

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