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Agro-morphological Characterization and Genetic Diversity of Similar Named Aromatic Rice (*Oryza sativa* L.) Landraces of Bangladesh

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ABSTRACT

Thirty-six similar named aromatic rice landraces of Bangladesh were studied to assess the genetic variation for the agro-morphological traits through Mahalanobis D^2 statistics. The landraces were grouped into four clusters, where no duplicate landrace was found. The inter-cluster distances were higher than intra-cluster distances indicating wider genetic diversity among the landraces of different clusters. The intra-cluster distances were lower in all the cases reflecting homogeneity of the landraces within the clusters. The principal component analysis showed that the first five components with vector values > 1 contributed 76.51% of the total variations. The highest number (13) of landraces was constellated in cluster III and the lowest (3) in cluster I. The intra- and inter-cluster distances were the maximum in cluster I (0.63) and between clusters I and IV (17.13), respectively and the minimum in cluster II (0.03) and between clusters III and IV (3.86), respectively. The maximum value of inter cluster distance indicated that the landraces belonging to cluster IV were far diverged from those of cluster I. So, it is expected in our results that parent's selection for hybridization from the clusters IV and I may give the desirable heterosis for heterotic rice hybrids. Besides, the cluster mean revealed that the crosses between the genotypes of cluster I with those of clusters IV would exhibit high heterosis for maximum good characters. Hence, yield, grain breadth, days to maturity, culm diameter, ligule length had maximum contribution towards genetic divergence. Besides, evaluation of agro-morphological characters demonstrated that the aromatic rice landraces under the present study possessed a considerable genetic diversity. Therefore, similar and duplicate named aromatic rice landraces need to be conserved in Genebank for future breeding programme.

Keywords: Genetic diversity, aromatic rice landraces, agro-morphological characters

INTRODUCTION

Aromatic rice is a special class of rice with high market value due to its superior grain qualities and pleasant aroma (Singh *et al.*, 2000a, b). The centre of diversity of aromatic rice in India is the foothills of Himalayas, covering Uttar Pradesh, Bihar and the Tarai region of Nepal. From there, aromatic rice germplasm spread to the other states of India and neighbouring countries like Bangladesh and adapted to the local environments (Khush, 2000). Bangladesh has a stock of more than 8,000 rice germplasm of which nearly 100 are aromatic (Hamid *et al.*, 1982; Islam *et al.*, 2016). The farmers of this country still grow their heirloom landraces which not only suit to their flavour but also provide food safety. Bangladesh is also the home to many locally adapted aromatic and quality rice landraces. Despite their low-yield potential, these landraces are grown for their high market and social values.

Aromatic rice landraces native to Bangladesh generally have short bold and medium bold grain type with mild to strong

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aroma (Shahidullah *et al.*, 2009; Islam *et al.*, 2013). A considerable number of aromatic rice landraces, namely Chinigura, Kalijira, Kataribhog, Begunbichi, Sakkorkhora and Sakkorkhana are grown in the different districts of Bangladesh. Among the different aromatic rice varieties, Chinigura is the predominant one that covers more than 70% of rice farms in the northern districts of Naogaon and Dinajpur. Other important aromatic rice varieties are Kalijira (predominantly grown in Mymensingh) and Kataribhog (mainly cultivated in Dinajpur) (Baqui *et al*., 1997). Most of the aromatic rice varieties in Bangladesh are locally adapted, photoperiod-sensitive and grown during Aman season under rainfed lowland ecosystem. However, the average yield of high yielding rainfed lowland rice is 3.4 t/ha, whereas that of aromatic rice is 2.0–2.3 t/ha (Das *et al*., 2005).

Exploring diversity in the landrace collection is very important for identifying new genes and further improvement of the germplasm (Thomson *et al*., 2007). However, it was identified that duplicate(s) named rice germplasm were cultivated all over Bangladesh (Hamid *et al.*, 1982). As a result, a particular cultivar got many slightly deviated names or even different cultivars got the same name given by different farmers. Hence, similar and duplicate named aromatic rice germplasm need to be studied whether they are same or different. It is true that some small and medium-grained aromatic rice landraces possess excellent aroma and other quality traits like elongation after cooking, taste etc. These could be excellent sources for improving quality in high yielding varieties. The improvement of aromatic rice landraces requires collection and evaluation of existing cultivars of Bangladesh. Genetic study of local germplasm of aromatic rice landraces is the pre-requisite for the development of high yielding varieties. Many researchers have performed studies on genetic diversity with local and high yielding varieties of rice (Siddique *et al*., 2013; Islam *et al*., 2014; Akter *et al.*, 2016; Ahmed *et al*., 2016 and Akter *et al.*, 2018). But such type of studies on similar named aromatic rice landraces has not yet been done. Therefore, the present study was undertaken to assess the genetic variation in 36 similar named aromatic rice landraces of Bangladesh by studying the agro-morphological traits.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the research farm of Bangladesh Rice Research Institute (BRRI), Gazipur, during July to December (T. Aman season), 2015. Geographically, the place is located at about 24.00 °N latitude and 90.25 °E longitude with an elevation of 8.4 meters from the sea level and is characterized by sub-tropical climate. The soil of the experimental site was clay loam in texture.

Crop materials

A total of 36 landraces of similar named Aromatic rice germplasm (Table 1) of Bangladesh were selected and collected from Rice Genebank of BRRI, Gazipur. Pre-germinated seeds were sown in the seed bed.

Experimental design and setting of the experiment

The experiment was conducted following randomized complete block design (RCBD) with three replications. Thirty days old seedlings from each entry were transplanted on the 20th August, 2015 using single seedling per hill in 2.4 m^2 plot following 25 cm and 20 cm space between rows and plants, respectively.

Intercultural operations

Fertilizers were applied @ 60:20:40:10 kg N, P, K and S per hectare. Total quantity of TSP, MP

Table 1. Information on place of collection, source and local name of the aromatic rice landraces.

Sl. no.	Landrace	Code name	Acc. no.	Season	Upazila/Institute	District	Origin	1.7% KOH (aroma)
1	Chinigura	C1	6719	T. Aman	Gazipur Sadar	Gazipur	Bangladesh	S
2	Chinigura	C2	2412	T. Aman	-	Dhaka	Bangladesh	LS
3	Chinigura	C3	4867	T. Aman	Phulpur	Mymensingh	Bangladesh	LS
4	Chinigura	C4	7572	T. Aman	Habiganj Sadar	Habiganj	Bangladesh	S
5	Chiniguri	C5	1424	T. Aman	-	Dhaka	Bangladesh	S
6	Chiniguri	C6	1880	T. Aman	Kishoreganj Sadar	Kishoreganj	Bangladesh	S
7	Sakkorkhora	S1	1605	T. Aman	Bauphal	Patuakhali	Bangladesh	S
8	Sakkorkhana	S2	4761	T. Aman	Betago	Barguna	Bangladesh	S
9	Sakkorkhana	S3	5338	T .Aman	Morrlganj	Bagerhat	Bangladesh	S
10	Sakkorkhana	S4	7316	T.Aman	Nalchity	Jhalakati	Bangladesh	LS
11	Sakkorkhana	S5	7500	T. Aman	Pirojpur Sadar	Pirojpur	Bangladesh	LS
12	Sakkorkhora	S6	7506	T. Aman	Pirojpur Sadar	Pirojpur	Bangladesh	S
13	Kataribhog	K1	232	T. Aman	Trishal	Mymensingh	Bangladesh	LS
14	Kataribhog	K2	1091	T .Aman	-	Jessore	Bangladesh	S
15	Kataribhog	K3	1491	T. Aman	Basail	Tangail	Bangladesh	S
16	Kataribhog TAPL-78	K4	2505	T. Aman	BRRI, GRSD	Gazipur	Bangladesh	S
17	Kataribhog TAPL-79	K5	2506	T. Aman	BRRI, GRSD	Gazipur	Bangladesh	S
18	Kataribhog TAPL-80	K6	2507	T. Aman	BRRI, GRSD	Gazipur	Bangladesh	S
19	Kataribhog TAPL-81	K7	2508	T. Aman	BRRI, GRSD	Gazipur	Bangladesh	S
20	Kataribhog TAPL-82	K8	2509	T. Aman	BRRI, GRSD	Gazipur	Bangladesh	S
21	Kataribhog TAPL-83	K9	2510	T. Aman	BRRI, GRSD	Gazipur	Bangladesh	S
22	Kataribhog TAPL-84	K10	2511	T. Aman	BRRI, GRSD	Gazipur	Bangladesh	S
23	Kataribhog TAPL-85	K11	2512	T. Aman	BRRI, GRSD	Gazipur	Bangladesh	S
24	Kataribhog TAPL-86	K12	2513	T. Aman	BRRI, GRSD	Gazipur	Bangladesh	LS
25	Kataribhog TAPL-87	K13	2514	T. Aman	BRRI, GRSD	Gazipur	Bangladesh	LS
26	Kataribhog TAPL-88	K14	2515	T. Aman	BRRI, GRSD	Gazipur	Bangladesh	S
27	Kataribhog	K15	4362	T. Aman	Gazipur Sadar	Gazipur	Bangladesh	S
28	Kataribhog	K16	4363	T. Aman	Gazipur Sadar	Gazipur	Bangladesh	S
29	Kataribhog	K17	4791	T. Aman	Kaharole	Dinajpur	Bangladesh	LS
30	Kataribhog	K18	7082	T. Aman	-	Sylhet	Bangladesh	LS
31	Begunbichi	B1	508	T. Aman	-	Rangpur	Bangladesh	LS
32	Begunbichi	B2	740	T. Aman	Rangamati Sadar	Rangamati	Bangladesh	LS
33	Begunbichi	B3	986	T. Aman	-	Khulna	Bangladesh	S
34	Begunbichi	B4	1465	T. Aman	Nawabganj	Dhaka	Bangladesh	LS
35	Begunbichi	B5	1678	T. Aman	-	Faridpur	Bangladesh	S
36	Begunbichi	B6	4088	T. Aman	Saidpur	Nilphamari	Bangladesh	NS

NS: Non-scented, LS: Light scented and S: Scented and TAPL: Transplant Aman Pure Line.

and gypsum were applied at the final land preparation. Urea was applied in three splits at 15, 30 and 45 days after transplanting (DAT). Intercultural operations and pest control measures were done as and when necessary.

Agro-morphological trait observation

Observed variables included both qualitative and quantitative agro-morphological characters of leaf, culm, panicle and grain. Observed qualitative characters included 25 characters namely blade pubescence, blade colour, leaf sheath: anthocyanin colour, basal leaf sheath colour, flag leaf angle, ligule colour, ligule shape, coller colour, auricle colour, culm:anthocyanin colouration of nodes, culm angle, internode colour, culm strength, panicle type, panicle exertion, spikelet: awns in the spiklet, spikelet: length of the longest awn, distribution of awing, awn colour, apiculus colour, stigma colour, lemma and palea colour, lemma and palea pubescence, seed coat (bran) colour, leaf senescence, decorticated grain: scent (aroma) while the observed quantitative characters included 14 traits and ten plants from each entry were randomly selected for recording data on ligule length (mm) , flag leaf area (cm^2), culm diameter (mm), effective tiller number, plant height (cm), days to flowering, days to maturity, panicle length (cm), filled grains per panicle, grain length (mm), grain breadth (mm), 1000-grain weight (g) and grain yield per hill (g). The observed qualitative traits were scored based on 'Germplasm Descriptors and Evaluation Form' issued by BRRI (2018) (Table 2).

Aroma test

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

Statistical analysis

Multivariate analyses were performed in computer using GENSTAT 5.5 programme.

RESULTS AND DISCUSSION

Qualitative traits characterization

The present study was aimed at identifying distinct qualitative traits variation among the tested aromatic rice landraces. Polymorphism was found in 17 of the 25 qualitative traits under studied; the non-polymorphic traits were the leaf sheath: anthocyanin colour, basal leaf sheath colour, ligule colour, ligule shape, collar colour, auricle colour, culm anthocyanin colour and stigma colour (Table 2).

Table 2. Classification of aromatic rice landraces based on 25 qualitative characters.

Sl. no.	Qualitative character	Classification	Frequency	Landrace (Serial number as in Table 1)	Frequency %
1	Blade pubescence	2. Intermediate	11	1, 7, 21,22,23,24, 25,26,27,35,36	30.55
		3. Pubescent	25	2,3,4,5,6,8,9,10,11,12,13,14,15,16,17,18,19,20,28, 29,30,31,32,33,34	69.45
2	Blade colour	1. Pale green	03	1,5,10,	8.33
		2. Green	33	2,3,4,6,7,8,9,11,12,13,14,15,16,17,18,19,20,21,22, 23,24,25,26,27,28,29,30,31,32,33,34,35,36	91.67
3	Leaf sheath: anthocyanin colour	1. Absent	36	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	100
4	Basal leaf sheath color	1. Green	36	1,2,3,4,5,6,7,8,9,12,13,14,15,16,17,18,19,20,21,22, 23,24,25,26,27,28,29,30,31,32,33,34,35,36	100
5	Flag leaf angle	3. Semi erect (<30-45°)	18	3,4,5,6,7,8,9,10,11,12,13,14,16,17,18, 20,21, 23,24,25, 27,28, 29,30,31,32,33, 36	72.22
		5. Horizaontal (<46-90°)	10	1,2, 10,11, 15, 19,22, 26,34,35	27.78
6	Ligule colour	1. White	36	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	100
7	Ligule shape	2. 2- cleft	36	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	100
8	Collar colour	1. Pale green	36	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	100
9	Auricle colour	1. Pale green	36	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	100
10	Culm anthocyanin colour	1. Absent	36	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,2 0,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35, 36	100
11	Culm angle	1. Erect(<30°)	13	6,8,9,16,18,19,20,26,29,30,31,33,36,	36.11
		3. Intermediate	15	1,2,4,5,7,10,12,13,14,15,17,21,22,25,28	41.67
		5. Open	08	3,11,23,24,27,32,34,35	22.22
12	Internode colour	1. Green	27	1,2,6,7,8,9,10,11,12,13,14,16,17,18,21,22,23,24,25 ,26,27,28,29,30, 32,33,34	75.00
		2. Light gold	09	3, 4,5,19,20,23, 31,35,36	25.00

Table 2. Continued.

Sl. no.	Qualitative character	Classification	Frequency	Landrace (Serial number as in Table 1)	Frequency %
13	Culm strength	1. Strong	04	6,8,25,36	11.11
		3. Moderately strong	29	1,2,4,5,7,9,11,12,13,14,15,16,17,18,19,20,21,22,23 , 24,26,27, ,28,29,30,31,32,33,34	80.55
		5. Intermediate	03	3,10,35	8.34
14	Panicle type	1. Compact	02	16, 25	5.56
		5. Intermediate	15	1,4,8,9,13,14,17, 21, 24, 28, 31,32,33,35,36	41.66
		9. Open	19	2,3,5,6,7,10,11,12,15,18,19,20,22,23,26,27,29,30, 34	52.78
15	Panicle exsertion	1. Well exerted	32	1,2,3,4,5,6,7,9,10,11,12,13,14,15,16,17,18,19,20,2 1,22,23,26,27, 29,30,31,32,33,34,35,36	88.88
		3. Moderately well exerted	02	8,28	5.56
		5. Just exerted	02	24,25	5.56
16	Spikelet: awns in the spikelet	1. Absent	23	1,2,3,4,5,6,7,8,9,10,11,12,18,22,23,24,25,31,32,33, 34,35,36	63.89
		9. Present	13	13,14,15,16,17,19, 20,21,26,27,28,29,30	36.11
17	Distribution of awning	1. Tip only	09	14,16,17,21,26,27,28,29,30,	69.23
		3. Upper half only	04	13,15,19,20,	30.76
18	Awn colour	1. Straw	10	13,14,15,16,17, 26,27,28,29,30,	76.93
		3. Brown	01	21	7.69
		6. Black	02	19,20	15.38
19	Apiculus colour	2. Straw	23	1,2,3,4,5,11,13,14,15,16,17,18,22,23,24,25,26, 27,28,29,30, 34, 36	63.89
		3. Brown	01	35	2.78
		4. Red	03	6,21,33	8.33
		5. Red apex	04	7,8,9,12	11.11
		6. Purple	05	10,19,20, 31,32,	13.89
20	Stigma colour	1. White	36	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	100
21	Lemma and palea colour	0. Straw	19	2,4,11,13,14,15,16,17,18,21,22,23,25,26,27,28,29, 30,35	52.78
		1. Gold	5	1,3,5,24,34	13.89
		3. Brown furrows on straw	8	7,8,9,10,19,20,31,32	22.22
		4. Brown	3	6,33,36	8.33
		5. Reddish to light purple	1	12	2.77
22	Lemma and palea pubescence	3. Hairs on upper portion	04	7, 8,9,32	11.11
		4. Short hairs	32	1,2,3,4,5,6,10,11,12,13,14,15,16,17,18,19,20,21,22 ,23,24,25,26,27,28,29,30,31,33,34,35,36,	88.89
23	Seed coat (bran) colour	1. White	34	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 21,22,23,24,25,26,27,28,31,32,33,34,35,36	94.44
		2. Light brown	01	30	2.78
		5. Red	01	29	2.78
24	Leaf senescence	5. Intermediate	15	3,7,10,11,13,14,16,18,19,22,23,25, 27,29,34,	41.67
		9. Early and fast	21	1,2,4,5,6,8,9,12,15,17,20,21,24,26,28,30,31,32,33, 35,36	58.33
25	Decorticated grain: Scent (aroma)	0. Non scented	1	36	2.78
		1. Lightly scented	13	2,3,10,11,13,24,25,29,30,31,32,34	36.11
		2. Scented	22	1,4,5,6,7,8,9,12,14,15,16,17,18,19,20,21,22,23,26, 27,28,33,35	61.11

Most of the characterized aromatic rice landraces (69.45%) exhibited pubescent leaf blade while the rest of the landraces exhibited intermediate (30.55%) leaf blade pubescence. We also observed in the present study that about 91.67% of the evaluated aromatic rice landraces exhibited a blade colour green while the remaining landraces (8.33%) exhibited pale green. Data in Table 2 also demonstrate variation in flag leaf angle where the percentage of aromatic rice landraces with semi erect and horizontal flag leaf are 72.22% and 27.78%, respectively. The qualitative characters showing higher variability were culm angle (36.11% erect, 41.67% intermediate and 22.22% open), internode colour (75% green and 25% light gold), culm strength (11.11% strong, 80.55% moderately strong and 8.34% intermediate), panicle type (5.56% compact, 41.66% intermediate and 52.78% open), panicle exsertion (88.88% well exserted, 5.56% moderately well exserted and 5.56% just exserted), spikelet: awns in the spikelet (63.89% absent and 36.11% present), distribution of awning (69.23% tip only and 30.76% upper half only), awn colour (76.93% straw, 7.69% brown and 19.20% black).

In the present study, it was also found that most of the tested landraces possessed straw apiculus colour (76.93%), straw lemma and palea colour (52.78%), short hairs on lemma and palea pubescence (88.89%), white seed coat colour (94.44%), early and fast type leaf senescence 58.33%). The present study exhibited high variability in most of the observed qualitative traits of aromatic rice landraces. Similar types of work was also reported by other authors (Bisne and Sarawgi, 2008; Moukoumbi *et al.*, 2011; Ahmed *et al*., 2016; Mau *et al.*, 2017 and Islam *et al.*, 2017). The unique and similar type aromatic landraces were found for different qualitative agro-morphological characters (Table 3) which could be used in hybridization programme regarding issues like distinctness of new variety and intellectual property rights. Besides, the grain morphology varied considerably in aromatic landraces collected from BRRI genebank (Fig. 1) with respect to awning, colour of awns, lemma and palea colour, lemma and palea pubescence and varied coloured apiculus.

Quantitative traits characterization

Table 4 shows eigen values (latent roots) and percentage of total variation accounted for them obtained from principle component analysis. The result exposed that the first five components in the PCA with eigen values >1, contributed 76.51% of the total variations among the genotypes for 14 morphological characters.

Islam *et al.* (2016) observed that the first nine axes accounted about 90% of the total variations by PCA in 113 aromatic and fine grain rice landraces. On the other hand, Sohrabi *et al.* (2012) and Chakravorty *et al.* (2013) observed the contribution of 76.7 and 75.9% of the first six and four components, respectively to the total variation in rice. Figure 2 presents a two dimension chart (Z_1-Z_2) of the aromatic rice landraces based on the principal axes I and II. As per the scattered diagram the landraces were apparently distributed into four clusters.

Based on the degree of divergence, 36 similar named aromatic landraces were grouped into four clusters on the basis of cluster analysis (Table 5). Maximum 13 landraces were grouped into the cluster III followed by 11 in cluster IV and 9 in cluster II. The cluster I contained the lowest (3) number of landraces. It also revealed that no duplicate was existed among the landraces for the studied characters. Similarly, Fukuoka *et al.* (2006), Hossain (2008), Sarhadi *et al.* (2009) and Nascimento *et al.* (2011) also found no duplicates from cluster analysis using Mahalanobis D^2 statistics in rice.

Table 3. List of unique and similar type Aromatic landraces for different qualitative traits.

Characteristic	Index value	Unique type	Similar type
Basal leaf sheath colour	1. Green	-	All landraces
Flag leaf angle	5. Horizaontal (<46-90°)	Chinigura (6719), Chinigura (2412), Sakkorkhana (7316), Sakkorkhana (7500), Kataribhog (1494), Kataribhog TAPL-81 (2508), Kataribhog TAPL-84(2511), Kataribhog TAPL-88 (2515), Begunbichi (1465) and Begunbichi (1675)	-
Ligule colour	1. White	-	All landraces
Ligule shape	2. 2- cleft	-	All landraces
Collar colour	1. Pale green	-	All landraces
Auricle colour	1. Pale green	-	All landraces
Culm anthocyanin colour	1. Absent	-	All landraces
Culm strength	1. Strong	Chiniguri (1880), Sakkorkhana (4761), Kataribhog TAPL-87 (2514) and Begunbichi (4088)	-
Panicle type	1. Compact	Kataribhog TAPL-78 (2504) and Kataribhog TAPL-87 (2514)	-
Panicle exsertion	5. Just exerted	Kataribhog TAPL-85 (2512) and Kataribhog TAPL-86 (2513)	-
Spikelet: awns in the spikelet	9. Present	Kataribhog (232), Kataribhog (1091), Kataribhog (1491), Kataribhog TAPL-78 (2505), Kataribhog TAPL-79 (2506), Kataribhog TAPL-81 (2508), Kataribhog TAPL-82 (2508), Kataribhog TAPL-83 (2510), Kataribhog TAPL-88 (2515), Kataribhog (4362), Kataribhog (4363), Kataribhog (4791) and Kataribhog (7082)	-
Apiculus colour	3. Brown	Begunbichi (1678)	-
	4. Red	Chiniguri (1880), Kataribhog TAPL-83 (2510) and Kataribhog TAPL-88 (2512)	-
	5. Red apex	Sakkorkhora (1605), Sakkorkhana (4761), Sakkorkhana (5338) and Sakkorkhora (7506)	-
	6. Purple	Sakkorkhana (7316), Kataribhog TAPL-81 (2508), Kataribhog TAPL-84 (2511), Begunbichi (508) and Begunbichi (740)	-
Stigma colour	1. White	-	All landraces
Lemma and palea colour	3. Brown furrows on straw	Sakkorkhora (1605), Sakkorkhana (4761), Sakkorkhana (5338), Sakkorkhana (7316), Kataribhog TAPL-81 (2508), Kataribhog TAPL-81 (2509), Begunbichi (508) and Begunbichi (986)	-
	4. Brown	Chiniguri (1880), Begunbichi (986) and Begunbichi (4088)	-
	5. Reddish to light purple	Sakkorkhora (7506)	
Lemma and palea pubescence	3. Hairs on upper portion	Sakkorkhora (1605), Sakkorkhana (4761), Sakkorkhana (5338) and Begunbichi (740)	
Seed coat (bran) colour	2. Light brown	Kataribhog (7082)	-
	5. Red	Kataribhog (4791)	-

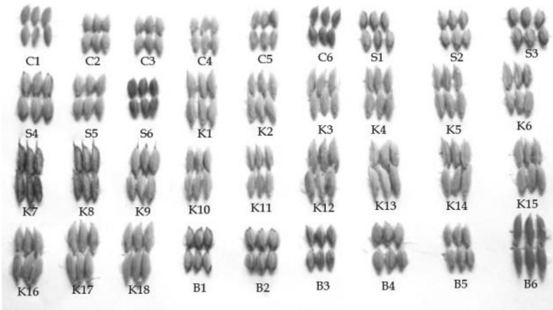

Fig. 1. Variation in grain morphology of 36 similar named aromatic rice landraces.

Note: C= Chinigura /Chiniguri type, K=Kataribhog type, S=Sakkorkhora/Sakkorkhana type and B=Begunbichi type

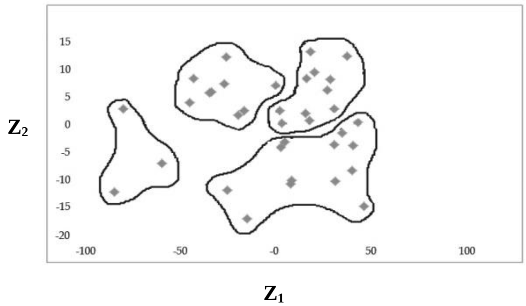

Fig. 2. Scatter diagram of 36 Aromatic rice landraces based on their principal component scores superimposed with clustering.

Table 4. Latent roots (Eigen values) and their variation in 14 quantitative characters in 36 aromatic landraces.

Character	Principal component axes	Latent roots	Variation (%)	Cumulative % of variation
Ligule length (mm)	PC 1	3.551	25.37	25.37
Flag leaf area (cm^2)	PC 2	2.328	16.63	42.00
Culm diameter (mm)	PC 3	2.126	15.19	57.19
Effective tiller number	PC 4	1.651	11.80	68.99
Plant height (cm)	PC 5	1.053	7.52	76.51
Days to flowering	PC 6	0.798	5.71	82.22
Days to maturity	PC 7	0.747	5.34	87.56
Panicle length (cm)	PC 8	0.579	4.14	91.7
Filled grains per panicle	PC 9	0.451	3.22	94.92
Grain length (mm)	PC 10	0.326	2.33	97.25
Grain breadth (mm)	PC 11	0.260	1.86	99.11
Grain length-breadth ratio	PC 12	0.070	0.50	99.61
1000 grain weight (g)	PC 13	0.053	0.37	98.00
Yield/hill (g)	PC 14	0.002	0.02	100.00

Table 5. Distribution of 36 aromatic rice landraces into four clusters

Cluster	No. of landrace	% total	Landraces with BRRI accession no.
I	3	8.33	Chinigura(1880), Sakkorkhana (5358), Bengunbichi(508)
II	9	25	Chinigura (6719), Chinigura (7572), Sakkorkhora (1605), Sakkorkhana (7316), Kataribhog TAPL-80 (2507), Kataribhog TAPL-84 (2511), Kataribhog (4791), Bengunbichi (740), Bengunbichi (4088)
III	13	36.11	Chinigura (2412), Chinigura (4867), Chinigura (1424), Sakkorkhana (4761), Sakkorkhana (7506), Kataribhog (232), Kataribhog (1491), Kataribhog Kataribhog TAPL-79 (2506), Kataribhog TAPL-85 (2512), KataribhogTAPL-86 (2513), Kataribhog TAPL-87 (2514), Bengunbichi (986), Bengunbichi (1465)
IV	11	30.56	Sakkorkhana (7500), Kataribhog (1019), Kataribhog TAPL-78 (2505), Kataribhog TAPL-81 (2508), Kataribhog TAPL-82 (2509), Kataribhog TAPL-83 (2510), Kataribhog TAPL-88 (2515), Kataribhog (4362), Kataribhog (4363), Kataribhog (7082), Bengunbichi (4088)

Table 6 presents Intra and inter-cluster distances. There were marked variations in intra-cluster distances,which ranged from 0.03 to 0.63. The highest intra-cluster distance was recorded in cluster I (0.63) containing three landraces followed by cluster IV (0.52) with eleven landraces. The lowest intra-cluster distance was observed in cluster II (0.03) having nine number of landraces and the cluster III showed the second lowest intra-cluster distance (0.45) having the highest (13) number of landraces. Such results indicated that the landraces of cluster I were more heterogeneous as compared to those included in cluster II.

The highest inter-cluster distance was observed between cluster I and IV (17.13) followed by clusters I and III (13.47) (Table 6). The lowest inter-cluster distance was observed between cluster III and IV (3.86) followed by cluster II and III (6.24). The maximum value of inter-cluster distance indicated that the landraces belonging to cluster IV was far diverged from those of cluster I. The minimum inter cluster divergence was observed between cluster III and IV (3.86) indicating that the landraces of these clusters were genetically closed. So, it is expected in our results that parent's selection for hybridization from the clusters IV and I may give the desirable heterosis for heterotic rice hybrids. On the other hand, the inter cluster distances in all the clusters were higher than the intra cluster distances suggesting wider genetic diversity among the landraces of different groups. The results were in agreement with Siddique *et al.* (2013) and Ahmed *et al*. (2015). Again, Islam *et al.* (2016) reported intra and inter-cluster distance ranged from 0.61 to 1.27 and 3.71 to 16.12, respectively on aromatic and fine rice genotypes.

Table 7 presents the mean performance of 14 characters in four clusters. The highest cluster means for yield, grain breadth, filled grain per panicle, days to maturity and ligule length were obtained from cluster I. The highest panicle length, plant height, effective tiller number, flag leaf area and lowest yield were found in cluster II. On the other hand, the lowest mean value for flag leaf area, days to maturity, filled grains per panicle and highest mean value for 1000 grain weight (TGW) and grain length-breadth ratio were found in cluster IV. The second highest mean yield was found in cluster III. The cluster mean revealed that the crosses between the genotypes of cluster I with those of clusters II and IV would exhibit high heterosis for maximum good characters. Ahmed *et al.* (2015) and Sohrabi *et al*. (2012) earlier reported similar trend of conclusions on rice germplasm using D^2 statistic

Table 8 presents contributions of the characters towards divergence. The canonical vector analysis revealed that the vectors (vector I and II) were positive for yield, grain breadth, days to flowering, days to maturity, culm diameter, ligule length. Such result indicated that those characters contributed maximum towards divergence. It is interesting that the greater divergence in the present materials due to those characters will offer a good scope for improvement of yield through rational selection of parents for producing heterotic rice hybrids. On the other hand, the other characters namely filled grains per panicle, panicle length, plant height, effective tiller number and leaf area index had the positive value for vector I, similarly, TGW, grain length-breadth ratio and grain length were found positive for vector II, which revealed that those characters was contributed less toward the total genetic divergence. Banumathy *et al*. (2010) reported that grain yield, days to fifty percent flowering, total grains per panicle and plant height contributed 86.64 per cent towards total divergence. On the contrary, Islam *et al*. (2014) also reported that panicle number per plant and TGW contributed maximum to the divergence in Sadajira TAPL rice.

Table 6. Intra (bold) and inter-cluster distances (D^2) for 36 aromatic rice landraces.

Cluster	I	II	III	IV
I	**0.63**	7.73	13.47	17.13
II		**0.03**	6.24	10.02
III			**0.45**	3.86
IV				**0.52**

Table 7. Cluster means for 14 quantitative characters in 36 aromatic rice landraces.

Character	I	II	III	IV
Ligule length (mm)	18.24	17.11	16.60	17.53
Flag leaf area (cm^2)	23.60	26.30	21.80	19.79
Culm diameter (mm)	3.39	3.79	3.72	3.50
Effective tiller number	11.00	14.00	13.00	12.00
Plant height (cm)	106.83	112.65	112.22	108.84
Days to flowering	103.00	98.00	96.00	95.00
Days to maturity	130.00	125.00	124.00	123.00
Panicle length (cm)	24.40	25.47	23.40	24.55
Filled grains per panicle	192.00	146.00	108	93.00
Grain length (mm)	6.23	7.09	7.49	8.30
Grain breadth (mm)	2.43	2.39	2.33	2.36
Grain length-breadth ratio	2.59	3.01	3.25	3.57
1000 grain weight (g)	13.18	14.16	14.89	17.03
Yield/hill (g)	14.81	12.54	12.97	12.77

Table 8. Latent vectors for 14 characters of 36 Aromatic rice landraces.

Character	Vector 1	Vector 2
Ligule length (mm)	0.1299	0.0882
Leaf area index (cm^2)	0.4203	-0.0873
Culm diameter (mm)	0.2325	0.0121
Effective tiller number	0.1216	-0.2448
Plant height (cm)	0.0853	-0.3006
Days to flowering	0.3409	0.4346
Days to maturity	0.3136	0.4394
Panicle length (cm)	0.0597	-0.2584
Filled grains per panicle	0.4595	-0.0204
Grain length (mm)	-0.3558	0.2748
Grain breadth (mm)	0.0590	0.2161
Grain length-breadth ratio	-0.4270	0.2146
1000 grain weight (g)	-0.2786	0.4538
Yield/hill (g)	0.1591	0.2358

CONCLUSIONS

The traditional Aromatic rice landraces can propose a valuable gene pool. They have considerable range of genetic variations for the studied 25 qualitative and 14 quantitative agro-morphological characters. The cluster analysis to be found 36 aromatic rice landraces into four groups. The highest inter- cluster distance was observed between clusters I and IV followed by clusters I and III. The maximum value of inter-cluster distance indicated that the landraces belonging to cluster IV were far diverged from those of cluster I. So, it is expected in our results that parent's selection for hybridization from the clusters IV and I may give the desirable heterosis for heterotic rice hybrids. Besides, the cluster mean revealed that the crosses between the landraces of cluster I with those of cluster IV would exhibit high heterosis for maximum good characters. Moreover, the studied 36 duplicate named aromatic rice landraces are not similar landraces for the studied agro-morphological characters. So, molecular characterizations using simple sequence repeats (SSRs) markers of the studied landraces are required for the confirmation of duplication and also for QTL mapping.

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