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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).

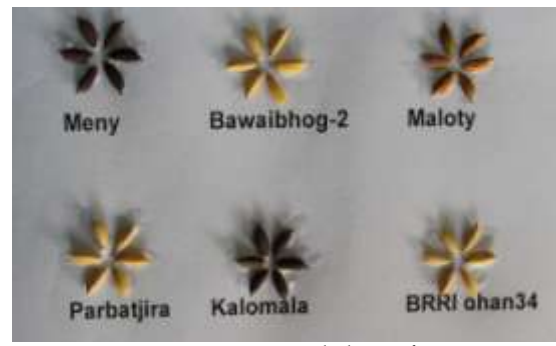

Fig. 1. Variation in grain morphology of some aromatic rice germplasm.

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, 75,76,81,82,83,85,86,87,88,89,90,91,92,93,94,98,99,100,1 01,107,108,109,111,112,113	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, 86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,10 3,104,105,106,107,108,109,110,111,112,113	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	1,2,4,5,6,7,11,12,14,15,16,17,19,20,21,23,25,26,27,28,32,3 3,36,37,39,40,42,43,45,46,50,51,53,55,56,57,58,62,63,64,6 5,68,69,72,73,74,75,76,77,78,79,80,82,84,85,86,87,92,93,9 4,95,96,97,98,99,100,101,102,103,104,105,106,107,108,10 9,110,111,112	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.

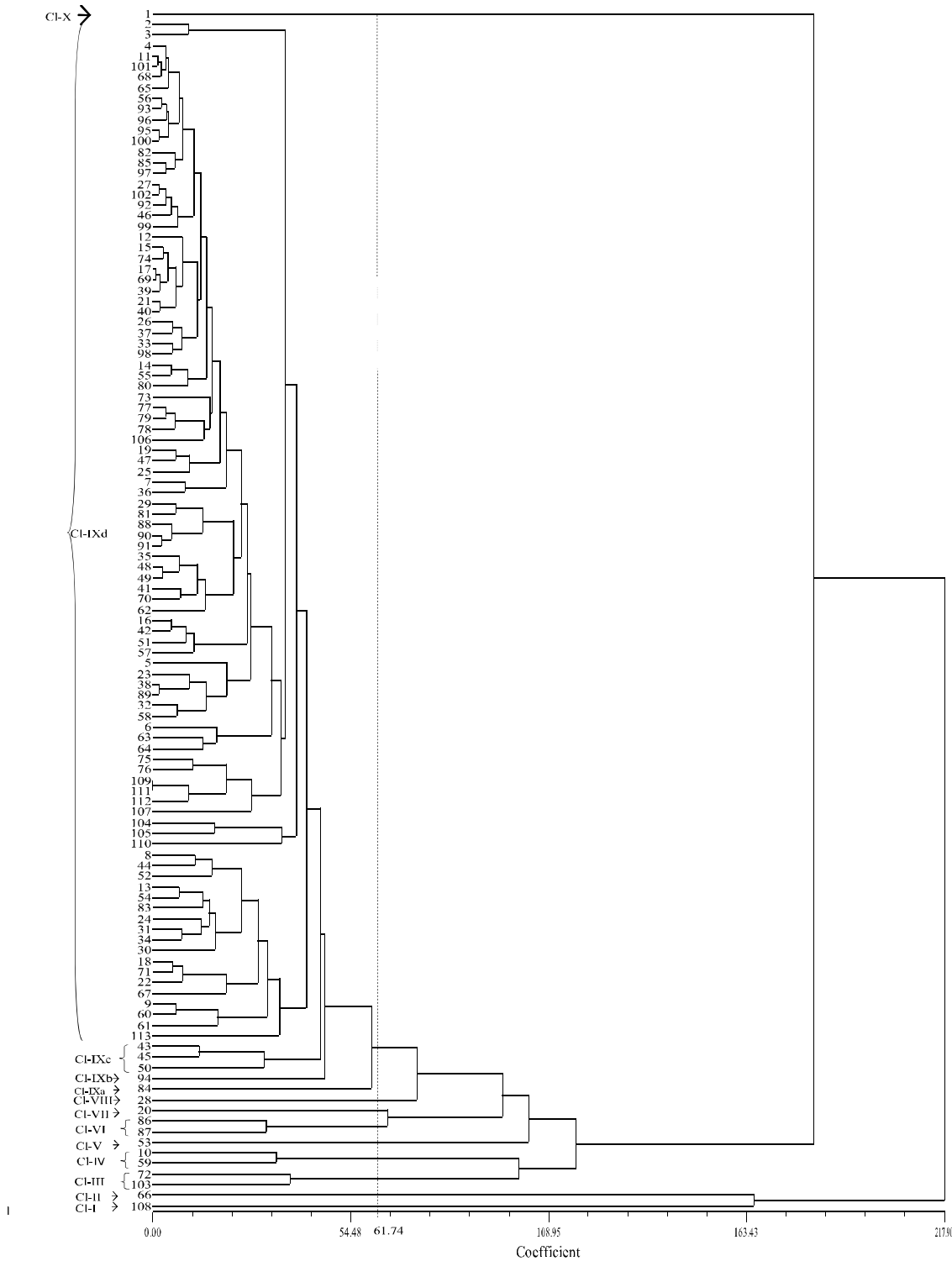

Fig. 2. Dendrogram of 113 test germplasm based on 28 qualitative traits.

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

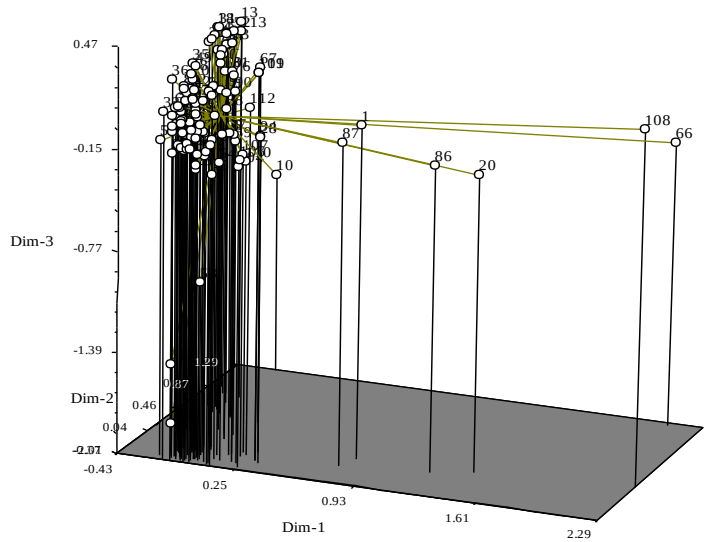

Fig. 3. There-dimensional view of principal co-ordinate analysis (PCoA) of 113 aromatic germplasm with 28 qualitative traits.

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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