Agro-morphological Characterization of Bangladesh 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, 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. Collar colour (late vegetative stage), 10. Auricle colour (late vegetative stage), 11. Culm: anthocyanin colouration of nodes (after flowering), 12. Culm angle (after flowering), 13. Internode colour (after flowering), 14. Culm strength (after flowering to maturity), 15. Panicle type (near maturity), 16. Secondary branching (near maturity), 17. Panicle exsertion (near maturity), 18. Spikelet: awns in the spikelet, 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).
| Germplasm              | Acc. No. | District/Source | Germplasm | Acc. No. | District/Source |
|------------------------|----------|-----------------|-----------|----------|-----------------|
| Sakor                  | 197      | Mymensingh      | Khasa     | 682      | Cumilla         |
| Sagardana              | 229      | Mymensingh      | Buchi     | 369      | Gaibandha       |
| Nuniya                 | 233      | Mymensingh      | Awned TAPL545 | 2939   | GRSD, BRRI     |
| Chini Sagar (2)        | 245      | Mymensingh      | Black TAPL554 | 2947   | GRSD, BRRI     |
| Meny                   | 288      | Gaibandha      | Straw TAPL500 | 2898   | GRSD, BRRI     |
| Tilkapur               | 296      | Gaibandha      | Dubsail   | 4840     | Satkhira       |
| Binnaphul              | 315      | Gaibandha      | Duksaile  | 2028     | Satkhira       |
| Kalobbhog              | 318      | Gaibandha      | Kyaskani  | 4341     | Jashore        |
| Jabsiri                | 331      | Gaibandha      | Khazar    | 4921     | Iran           |
| Kalgochi               | 352      | Gaibandha      | Basmati sufaid106 | 4498  | Pakistan       |
| Chinisakkor            | 387      | Rajshahi       | BR5       | 4543     | 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   | Khagrachchari  |
| Begunmala              | 1896     | Kishoreganj    | Uk nimodhu | 298     | Gaibandha      |
| Gopalbhog              | 1938     | Kishoreganj    | Bawa bhog-2 | 301    | Gaibandha      |
| Tulsimoni              | 1980     | Jalalpur       | Chiniatob-2 | 398    | Rajshahi       |
| Jirabuti               | 1984     | Mymensingh     | Tilok kanchari | 758    | Chittagong    |
| Khirshabuti            | 1996     | Tangail        | Begun bich-2 | 508    | Rangpur       |
| Rajbut                 | 1999     | Tangail        | Chinarri  | 764      | Chottagram     |
| Soru kamina            | 2015     | Satkhira       | Bhatir chikon | 774    | Chittagong    |
| Kamini soru            | 2027     | Satkhira       | Gordo     | 1908     | Kishoreganj    |
| Doiarguru              | 2037     | Khulna         | Dolagocha | 451      | Rajshahi       |
| Premful                | 2041     | Satkhira       | Kalonunia | 537      | Rangpur        |
| Begun bich            | 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 sambad | 4803   | Rajshahi       |
| Chini Kanai            | 4356     | Khulna         | Basmati   | 4754     | Barguna        |
| Kalijira (short grain) | 4357     | Khulna         | Basmati 37 | 4491     | India          |
| Rajbhog                | 4360     | Khulna         | Basnatu sufaid187 | 4499  | Pakistan       |
| Philliphine kataribhog| 4365     | Dinajpur       | Tulsimala-2 | 7342   | Sherpur        |
| Baolbhog               | 4813     | Kurigram       | Chinisal  | 7343     | Sherpur        |
| Baopjhike              | 4826     | Dinajpur       | Malshira  | 7347     | Sherpur        |
| Jirabhog(Bolder)       | 4828     | Dinajpur       | Sadagura  | -        | Khabragcharhi  |
| Chini gura             | 4867     | Mymensingh     | Modhumadab | 7352    | Habigang       |
| Tulsimala              | 4870     | Mymensingh     | Parbatjira | 7351   | Habigang       |
| Bashmati 370           | 4904     | Pakistan       | Chinikanai-2 | 7350  | Dinajpur       |
| Uknimodhu              | 5083     | Ranpur         | 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     | Barguna        | 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       | Kalijira TAPL-64 | 2492  | GRSD, BRRI     |
| Sugandhi dhan          | 7063     | Nawabganj      | Oval TAPL-2990 | 2990  | GRSD, BRRI     |
| Kalijira (long grain)  | 4358     | Khulna         | Kalijira TAPL-68 | 2496  | GRSD, BRRI     |
| Jesse balam TAPL-25    | 2454     | GRSD, BRRI     | Kalijira TAPL-74 | 2501  | GRSD, BRRI     |
| Dakshahi               | 983      | Khulna         | Kalobakri | 2108    | Narsingdi     |

Agro-morphological Characterization of Bangladeshi Aromatic Rice 43
Aroma test
Aroma was detected by snifffing 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 NTSYSpc 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 agromorphological character was also reported by Ahmed et al. (2015).

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

| Character                  | Classification | Frequency | Number of aromatic germplasm Frequency | 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       | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113 Nil |
| Collar colour             | 01. Pale green | 108       | 2,3,4,5,6,7,8,9,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,109,110,111,112,113 95.58 |
|                          | 03. Purple     | 05        | 1,10,66,94,108 4.42 |
| Auricle colour            | 01. Pale green | 113       | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,109,110,111,112,113 Nil |
| Culm anthocyanin colour   | 01. Absent     | 110       | 2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,109,110,111,112,113 96.46 |
|                          | 09. Present    | 04        | 20,66,86,108 3.54 |
| Culm Angle                | 01. Erect (<30') | 33        | 2,3,5,7,12,21,22,27,35,36,40,41,43,44,46,47,48,52,53,57,6 29.21 |
|                          | 03. Intermediate | 68        | 4,6,8,9,10,11,13,14,15,16,17,19,20,23,24,25,26,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,109,110,111,112,113 60.18 |
|                          | 05. Open       | 12        | 1,18,28,50,67,75,76,83,107,109,111,113 10.62 |
| Internode colour          | 01. Green      | 89        | 4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,86,87,89,90,91,93,94,95,96,98,99,100,101,102,103,104,105,106,107,109,110,111,112,113 78.76 |
|                          | 02. Light gold | 20        | 2,3,6,7,5,76,77,78,82,85,88,89,91,97,104,105,107,109,110 ,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        | 2,25,43,45,46,60,77,78,79,80,84,85,95,96,97,102,105,106,110 | 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        | 1,4,5,6,7,8,9,11,12,13,14,15,16,17,18,21,22,23,24,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,71,73,74,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,101,103,104,106,108,109,110,111,112,113,114 | 85.84       |
|                         | 09. Open           | 07        | 2,3,7,56,108,109,111        | 6.19        |
| Secondary branching     | 01. Light          | 68        | 1,2,3,6,7,8,9,10,12,13,14,15,17,18,21,22,23,24,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,73,74,75,78,80,82,83,84,85,87,88,92,93,94,95,96,97,98,99,100,102,105,107 | 59.29       |
|                         | 02. Heavy          | 46        | 4,5,11,16,19,20,24,27,30,31,32,33,34,35,36,42,46,47,56,58,65,68,69,73,74,75,78,80,82,83,84,85,87,88,92,93,94,95,96,97,98,99,100,102,105,107,111,112,113,114 | 40.70       |
| Panicle exsertion       | 01. Well exserted  | 107       | 1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,92,93,94,95,96,97,98,99,100,101,102,103,104,106,108,109,110,111,112,113,114 | 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        | 1,2,4,5,6,7,11,12,14,15,16,17,19,20,21,23,25,26,27,28,32,33,36,37,39,40,42,43,45,46,50,51,53,55,56,57,58,62,63,64,65,68,69,72,73,74,75,76,77,78,9,80,82,84,85,87,88,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112 | 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        |
| Character | Classification | Frequency | Number of aromatic germplasm | Frequency % |
|-----------|----------------|-----------|-------------------------------|-------------|
| Awn colour | 05. Whole length | 12 | 9,10,18,22,52,59,60,61,66,71,113,114 | 10.61 |
| 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 | 2,3,4,11,12,15,18,21,22,23,25,26,27,30,31,33,34,40,42,43,46,50,51,58,59,66,77,78,79,84,86,92,94 | 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, | 29.20 |
| 01. White | 100 | 1,2,3,4,5,6,7,9,10,11,12,13,14,15,16,17,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,43,45,46,47,53,54,55,56,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113 | 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 | 00. Straw | 54 | 3,4,7,11,14,17,18,19,21,22,23,24,25,26,27,30,31,32,33,34,35,36,38,39,40,41,42,43,46,50,51,52,53,55,56,58,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,88,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113 | 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 | 5,16,29,33,52,54,57,73,77,79,94,99, | 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 |
| 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        | 2,3,7,9,10,11,14,17,18,19,20,21,22,23,24,25,26,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,46,47,48,49,50,53,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,75,80,84,85,86,87,88,89,91,92,93,94,96,97,98,101,103,105,106,107,110,111,112 | 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. Lightly 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 indivisual 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, culm 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
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 similar 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.

Agro-morphological Characterization of Bangladeshi Aromatic Rice  51
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               | Ranasalut, Gandhakusturi, Thakurbhog   |
| IXd     | 96              | Sagardana, Nunia, Chini Sagar (2), Meny, Tilkapur, Binaphul, Kalobhog, Jabsiri, Chinisakkor, Chiniatob, Noyonmoni, Saubail, Chinniguri, Kalomala, Begumnala, Gopalbhog, Tulsimoni, Khirshabuti, Rajbut, Soru kamina, Kamini soru, Doiarguru, Premful, Begun bitchi, Gua masuri, Luina, Lal Soru, Chini Kanai, Kalijira (short grain), Rajbhog, Phillipine kataribhog, Baoibhog, Baoijhaki, Jirabhog (Bolder), Chinigura, Tulsimala, Bashmati 370, Uknimodhu, Jira dhan, Sakkor khora, Badshabhog, Jirakatari, Desikatari, Tulsimaloty, Radhuni pagal, Kalijira (long grain), Jessoalam TAPL-25, Dakshahi, Hatisail TAPL-101, Khasa, Awnedd TAPL-545, Black TAPL-554, Straw TAPL-554, Dubsail, Dukusail, Khaskani, Basmati sufaid 106, BR5, BRRI dhan34, BRRI dhan37, BRRI dhan38, Khasa Mukpura, Uknimodhu, Bawaibhog-2, Chiniatob-2, Tilokkachari, Begunbitchi-2, Chiniirri, Bhatir cikon, Gordoi, Dolagocha, Kalonunia, Badshabhog-2, Sunduri samba, Basmati, Basmati 37, Basmatu sufaid 187, Tulsimala-2, Chinisail, Sadagura, Modhumadab, Parbatjira, Chinkanai-2, Meedhan, Gobindabhag, Kataribhog, Fulkari, Padmabhag, 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 bitchi, Baoi jhaki, Jirabhog (Bolder), Ranasalut, Basmati sufaid-106, BRRI dhan50, Kalonunia, Dhan chikon, Khuti chikon, Basmati-37, Basmatu sufaid-187, Tulsimala-2, Chinisail, Malshira, Sadagura, Modhumadab, Parbatjira, Chinkanai-2, Meedhan, Gobindabhag, Fulkari, BU Dhan2R, Padmabhag, Dudsail, Maloti, OvalTAPL-2990 |
| Scented                        | 67                  | Chini Sagar (2), Meny, Kalobhog, Jabsiri, Kalgochi, Chinisakkor, Chini atob, Noyonmoni, Saubail, Kolomala, Chinniguri, Begumnala, 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 katuri, Tulsimaloty, Radhuni pagal, Kalijira (long grain), Jessoalam, Hatisail, Khasa, Buchi, AwnedTAPL-545, BlackTAPL-554, StrawTAPL-550, Dubsail, Khaskani, BR5, BRRI dhan34, BRRI dhan37, BRRI dhan38, Khasa Mukpura, Uknimodhu, Bawaibhog-2, Chiniatob-2, Tilokkachari, Begunbitchi-2, Chiniirri, Bhatir cikon, Badshabhog-2, Basmati, Kataribhog, Sakkorkhana, Bashful, KalijiraTAPL-64, OvalTAPL-2990, Kalijira TAPL68, Kalijira TAPL74, Kalobakri |
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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