THE EXPERIMENT
INTERNATIONAL JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN-2319-2119

RESEARCH ARTICLE

MA Siddique et al, The Experiment, 2018, Vol 45(4), 2598-2610

Agro-Morphological Characterization of Geographical Indication Rice Cultivars Grown in Bangladesh

Abstract:
The morphological characterization of plant is the basic criteria in order to provide fundamental information for plant breeding programme. The present study was conducted to characterize the geographical indication (GI) rice cultivars grown in Bangladesh on the basis of morphological characteristics at Bangladesh Rice Research Institute, Gazipur. The data were recorded on 53 different agro-morphological traits (37 qualitative and 16 quantitative). The rice germplasm exhibited sufficient genetic variation for most of the qualitative and quantitative traits. Variation was observed for all the qualitative traits except ligule color, leaf blade pubescence and panicle threashability. Rice cultivar Begunbichi took minimum days to 50% flowering; Pashusail and Digha showed superiority for panicle length; Horkoch showed the maximum value for 1000-grain weight and Pashusail showed the highest yield potential. The genetic potential of cultivars Pashusail, Biruin, Balam, Digha, Horkoch, Binni and Begunbichi on account of excellent performance for various traits can be used in future rice breeding programmes.

Key words: Agro-morphological traits, characterization, cultivars, GI rice

1. Introduction:

Rice (*Oryza sativa* L) is an economically important crop that accounts for ~20% of the world's caloric intake and it is the staple food for about 50% of the global population [1, 2]. It has been cultivated in Asia since ancient times and for generations farmers have maintained thousands of different landraces [3]. Now, 90% of world rice is produced in Asia on an area of almost 150 million hectares. Rice accounts for 50% of agricultural income in Asia and supplies almost 80 per cent of the region's nutrition. In Bangladesh rice engages more than 70% of the rural population and is central to agriculture and the national economy [4]. In fact, 'Rice security' is synonymous to 'Food security' in Bangladesh as in many other rice growing countries [5].

Due to great significance and intimate association of rice in food security and local ways of life and culture, Asian farmers have selected and maintained a vast array of rice landraces over thousands of years. Scientists estimate that more than 1,40,000 rice varieties have been developed/selected/isolated in Asia. More than 1,27,000 rice accessions and wild relatives can be found in the world's largest gene bank for rice at IRRI (International Rice Research Institute) located in the Philippines (http://irri.org/our-work/research/genetic-diversity). Until now, Bangladesh Rice Research Institute (BRRI) has collected and preserved more than 8,000 varieties/land races/cultivars/wild types from indigenous and exotic sources in BRRI genebank [6]. Among them, 20 rice cultivars widely cultivated in different regions of the country for commercial purpose due to their special characters and are known as geographical indication (GI) rice.

Geographical indications (GIs) deal with local issues and specific geographical location. GIs were first protected in France, later harmonized in the European Union and then included in the Trade Related Intellectual Property Rights (TRIPS) Agreement, which was the basis for the enactment of the GI Act in India and GI protection in Pakistan. GI recognizes that a given quality, reputation or other characteristic of the good is essentially attributable to its geographical origin, and is markedly different from other instruments of intellectual property rights. As GIs deal with local issues, their protection generates an original scheme of governance [7].

Research has been conducted on Bangladeshi local landraces in the world by many scientists, but research on indigenous landraces in BRRI is very limited. Only few years ago a large number of farmers grew these local cultivars as their main crop. These cultivars have good adaptation but are poor yielder. Actually, cultivation of these landraces gradually has been replaced through high yielding variety last twenty years. In Bangladesh, rice is grown in three seasons namely Aus, Aman and Boro. BRRI genebank enriched with about 5000, 1700, 1500 germplasm for Aman, Boro and Aus season respectively. These landraces are adapted in different parts of the country, some of which have very nice quality, fineness, aroma, taste and high protein content [8].

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INTERNATIONAL JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN-2319-2119

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Evaluation and characterization of existing landraces of rice is important due to increasing needs of varietal improvement. Agro-morphological characterization of germplasm variety is fundamental in order to provide information for plant breeding programme [9]. Yawen *et al.* [10] studied the genetic diversity of 5285 accessions of landraces of rice in China and found considerable morphological variation among accessions. Siddique *et al*. [11, 12, 13] analyzed the agro-morphological diversity of local Boro rice, hilly (Jhum) rice landraces and local rainfed rice of Bangladesh respectively. The main objective of the present study was to characterize the 20 GI rice cultivars grown in Bangladesh using 53 agro-morphological characters to provide useful information to facilitate the choice of genitors for future rice breeding programme.

2. Materials and Methods:

2.1. Selection of cultivars for GI:

The centre of diversity or most concentrated area of cultivation of the respective GI was identified through discussion with experienced rice scientists and Department of Agriculture Extension (DAE) Officials at district and upazila level. Based on commercial values and specific area of coverage, 20 rice landraces of Bangladesh were selected as geographical indication rice cultivars (Table 1).

2.2. Field evaluation, data collection and record keeping:

Twenty GI rice cultivars were characterized through 53 different agro-morphological traits (37 qualitative and 16 quantitative). Seeding was done in the well prepared seed beds in their respective season of 2012-13. The seedlings were transplanted into well puddled field one month after seeding. Each cultivar was planted in two rows, with row length of 5.4 meter and row-row distance of 25 cm using randomized complete block (RCB) design with three replications. Fertilizers were applied @ 60:20:40:40 kg NPKS/ha. Total quantity of TSP, MoP and Gypsum were applied at the final land preparation. Urea was applied in three installments at 7, 25 and 35 days after transplanting. Control measures for pests, diseases and weeds were taken whenever necessary. Among the 53 traits 37 qualitative traits on which the data were recorded were leaf blade pubescence, leaf blade colour, leaf sheath colour anthocyanin, basal leaf sheath color, leaf angle, flag leaf angle, ligule color, ligule shape, collar colour, auricle colour, anthocyanin colour of nodes, culm angle, internode color, culm strength, panicle type, secondary branching of panicle, panicle exertion, panicle axis type, shattering of panicle, threashability of panicle, awning, distribution of awn, awn color, apiculus colour, stigma colour, stigma exertion, lemma and palea colour, lemma and palea pubescence, sterile lemma colour, spikelet sterility, brown rice shape, seed coat color, endosperm type, decorticated grain scent and leaf senescence. Similarly, among the studied 16 quantitative traits were leaf length (cm), leaf width (cm), ligule length (cm), culm length (cm), total tiller number per hill, culm diameter, panicle length (cm), number of effective tillers per hill, heading Days, 1000-grain weight (g), grain length (mm), brown rice length (mm), brown rice width (mm), days to maturity and grain yield hil^{-1} (g). The data were collected on five randomly selected plants from each cultivar.

2.3. Data analysis

Mean, Standard deviation and Co-efficient of variation were analyzed using a total of 16 quantitative parameters. Statistical analyses were carried out using Microsoft Excel 2010.

3. Results and Discussion:

3.1. Qualitative Characters:

3.1.1. Leaf characteristics

Rice genotypes were characterized for leaf traits and divergence was observed among the cultivars for most of the characters (Table 2). Cultivar Digha showed dark green color while the remaining green to pale green leaf blade color was noted. Similarly for basal leaf sheath colour, Chamara and Tulsimala were found to have light purple, Birpala with purple lines while in the remaining cultivars green basal leaf sheath. Chamara and Tulsimala had anthocyanin colour in leaf sheath while absent for the remaining cultivars. For leaf angle, Pashusail, Birpala, Radhunipagal and Chamara showed drooping type;

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while in the remaining cultivars were erect leaf angle. Similarly for flag leaf angle, Biruin, Kalijira and Begunbichi showed horizontal type (<46-90º), Digha with descending (>90º) and the remaining cultivars showed erect (<30º) flag leaf angle.

3.1.2. Ligule characteristics

For ligule shape, Begunbichi, Balam, Pashusail, Digha and Galon showed acute to acuminate type while the remaining cultivars had 2-cleft ligule shape. For collar and auricle color, Birpala and Joina showed purple colour while the remaining cultivars had pale green ligule and auricle. There was no divergence found in ligule colour and leaf blade pubescence for the studied rice cultivars (Table 2).

3.1.3. Culm characteristics

Culm angle is an indicator of the growth habit of a particular species. During current study valuable variation was observed among the accessions for culm angle. Cultivar Dadkhani and Pashusail was found to have procumbent (the culm or its lower part rests on ground surface); Kalijira, Katarivhog and Bashful had erect (<30º); Binni, Chamara and Radhunipagal had spreading (>60º) type, Topa, Horkoch, Birpala and Joina had open (~60º) type and in the remaining accessions intermediate (~30-45º) culm angle was observed. Variation was observed among the cultivars for internode color. Begunbichi, Chamara, Tulsimala and Joina showed purple lines, Chinigura, Binni, Digha and Birpala had light gold and the remaining accessions was observed green internode color. For culm strength, Chinigura, Dadkhani, Pashusail and Radhunipagal showed weak, Kalijira and Topa observed moderately strong, Biruin, Binni and Birpala had intermediate type and the remaining observed strong culm (Table 3).

3.1.4. Panicle characteristics

Valuable variation was observed among the accessions for panicle characters. 40% panicles were open, 30% were compact and the rest 30% were intermediate type. 55% cultivar had light and the rest 45% had secondary branching in panicle. 75% cultivars exhibited well exertion panicle, 20% had moderately well exertion and the cultivar Pashusail had partly exertion panicle. 85% cultivar had droopy type and the remaining 30% had straight panicle axis. 70% cultivar had low shattering, 15% had moderate and the remaining 15% had moderately high shattering. All the cultivars showed easy for panicle threashability (Table 3).

3.1.5. Grain traits

Awn was not observed in 70% cultivar and the remaining 30% cultivars (Pashusail, Katarivhog, Chamara, Bashful, Birpala, Joina) had awn in spikelets. Joina had very short purple colour awn and distributed in tip only; Katarivhog, Bashful and Birpala had short (2-5mm) awn and distributed in tip only; Pashusail had medium and Chamara had very long (>20mm) awn distributed in whole length of their spikelets. The stigma colours of most of the cultivars were white except Birpala, Joina, Tulsimala and Chamara had purple colour. The stigma exsertion were low (5-20%) to medium (21-40%) except Tulsimala had high (41-60%). The lemma and palea of most of the cultivars were straw colour, whereas Kalijira and Radhumipagal had black; Pashusail and Kataribhog had gold and Tulsimala had reddish to purple in colour. Most of the cultivars had short hairs in lemma and palea whereas Begunbichi, Balam and Galon had hairs on upper portion of lemma and palea. Kalijira and Tulsimala had purple colour sterile lemma; Horkoch had red and the rest of the cultivars had straw colour. In case of spikelet fertility, the cultivars showed fertile (75-90%) to highly fertile (>90%) except Radhunipagal had partly sterile (50-74%). Brown rice shapes of the GI cultivars were medium slender (L:W= 2.6-3.0) to slender (L:W>3.0) and seed coat colour showed variability and distinctness (Fig. 1). The endosperm types were intermediate to non-glutinous (Table 4).

3.2. Quantitative traits:

3.2.1. Leaf traits:

Leaf length among the rice cultivars varied from 40.6 to 72.4 cm. Minimum values (40.6 cm) of leaf length was found for Biruin and maximum (72.4 cm) for Pashusail cultivar with an average of 50.2 cm. Leaf width among rice cultivars was ranged from 0.5 to 1.5 cm. Rice cultivar Begunbichi showed minimum leaf width (0.8 cm) and thus representing the most narrowed leaf among the rice cultivars whereas the maximum value of leaf width (1.5 cm) was observed in Balam with an average of 1.69 cm (Table 5).

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3.2.2. Ligule traits:

Ligule length among the rice cultivars varied from 11.4 to 18.2 mm. Minimum values (11.4 mm) of ligule length was found for Begunbichi and maximum (18.2 mm) for Horkoch cultivar with an average of 15.22 mm (Table 5).

3.2.3. Culm traits:

Culm length among the rice cultivars varied from 72.0 to 128.6 cm. Minimum values (72.0 cm) of leaf length was found for Binni and Dadkhani, and maximum (128.6 cm) for Pashusail cultivar with an average of 96.52 cm. Culm diameter among rice cultivars was ranged from 3.32 to 6.18 mm. Rice cultivar Katarivhog showed minimum culm diameter (3.32 mm) and the maximum value of culm diameter (6.18 mm) was observed in Pashusail with an average of 4.32 mm (Table 5).

3.2.4. Tillering traits:

Total number of tillers ranged from 5 to 22. The minimum number of tillers (5) was recorded in Galon, hilly rice and the maximum number of tillers (22) was observed in Biruin. The number of effective tillers ranged from 5 to 18. The minimum number of effective tillers (5) was recorded in Galon, a hilly rice and Horkoch and the maximum number of effective tillers (18) was observed in Biruin (Table 5).

3.2.5. Flowering traits:

Days to 50% flowering among the rice genotypes ranged from 85 to 159 days. The cultivar Begunbichi took minimum days (85) to 50 % flowering while cultivar Pashusail exhibited maximum days (159) to 50 % flowering. Most of the rice cultivars took less than 100 days to 50 % flowering (Table 5).

3.2.6. Panicle traits:

Panicle length among the rice cultivars varied from 21.00 to 28.40 cm. The cultivar Begunbichi exhibited minimum panicle length (22.22cm) whereas cultivar Bashful and Digha showed maximum value of 28.40cm for panicle length with an average of 25.32cm (Table 5).

3.2.7. Grain traits:

Range of grain length among the rice cultivars varied from 6.45 to 9.54 mm. The cultivar Kalijira showed minimum grain length (6.45 mm) whereas Binni exhibited maximum grain length (9.54 mm) with an average of 8.10mm. Grain width among the rice genotypes varied from 1.63 to 2.42 mm. Minimum value of grain width (1.63 mm) was recorded for the cultivar Tulsimala, while the Chamara showed maximum grain width (2.42 mm) with an average of 1.99 mm. For Brown rice, maximum grain length (8.12 cm) was observed in Digha and minimum (4.28 cm) in Kalijira with an average of 5.92 cm. The lowest grain width (1.48 mm) was recorded in Tulsimala and highest (2.36 mm) in Sadamota with an average of 1.80 mm (Table 5).

3.2.8. Yield traits:

Range of grain yield among the rice cultivars was from 6.38 to 20.93 g/hill. The cultivar Begunbichi exhibited minimum grain yield 6.38 g/hill, whereas the cultivar Pashusail showed maximum grain yield of 20.93 g/hill with an average grain yield of 10.57 g/hill. 1000-grain weight ranged from the studied cultivars was found within the range of 11.9 to 32.0 gm. The cultivar Chinigura exhibited minimum 1000-grain weight (11.9 g), whereas cultivar Horkoch showed maximum (32.0 g) 1000-grain weight with an average of 21.56 g (Table 5).

The rice germplasm used in the present study displayed variability for most of the studied traits with the exception of ligule colour, leaf blade pubescence and panicle threashability. Marked variation was observed for culm length, leaf length, tiller number, yield and days to 50% flowering.

Characterization of crop germplasm through different morphological traits is an important step for assessment of its genetic potential. Our present finding shows great genetic potential of the studied cultivars. The promising cultivars identified during the current study have the potential to be used in future breeding programmes for getting productive and quality results. During the current study for most of the qualitative and quantitative traits positive differences were found. Our results are in close agreement with those of Mohammad *et al*. [14], who recorded highly significant variability among the different rice genotypes. Similarly the finding of Wang *et al*. [15] also gives support to the current findings. The current

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results of agro-morphological evaluation of rice germplasm are supported by the study of Caldo *et al*. [16]. The findings of Abarshahr *et al*. [17] further strengthen the current findings, who also found valuable and highly significant and positive variability among their studied genotypes.

4. Conclusion:

The present study revealed sufficient genetic divergence for various qualitative and quantitative traits. Rice cultivar Begunbichi took minimum days to 50% flowering while cultivar Pashusail and Digha showed superiority for panicle length. Rice cultivar Pashusail showed excellent performance for grain yield while cultivar Horkoch showed the maximum value for 1000-grain weight. Similarly, the rice cultivar Pashusail showed superiority for leaf length, Balam for leaf width, Biruin for tillering, and cultivars Binni, Chamara, Digha and Sadamota showed superiority for various traits. The genetic potential of the mentioned cultivars for the desired traits can be utilized in future rice breeding programs to get promising results.

5. Tables and Figure:

Table 1. Rice cultivars used in the present study with their provenance.

Sl. no.	Name	BRRI Accession no.	Season	Major growing area and location	Special characters
1	Biruin	4887	T. Aman	Mymennsingh (24° 45' 0N, 90° 24' 0E, 16m), Sylhet (24° 53'48N, 91° 52' 18E, 10m), and Habiganj (24° 22'60N, 91° 25' 0E, 5m)	Tasteful, sticky
2	Kalijira	4755	T. Aman	All around the country	Aromatic, Tasteful, small grain
3	Topa	962	Boro	Mymensingh (24° 45' 0N, 90° 24' 0E, 16m)	Tasteful, slender, aromatic
4	Begunbichi	4563	Boro	Mymensingh (24° 45' 0N, 90° 24' 0E, 16m)	Aromatic, small grain
5	Chinigura	4867	T. Aman	All around the country	Aromatic, Good for Polao
6	Balam	4945	T. Aman	Barisal (22° 42' 7N, 90° 22' 16E, 1m)	Slender, Aromatic
7	Dadkhani	6721	T. Aman	Rajshahi (24°22' 0N, 88° 35' 60E, 18m)	Slender
8	Binni	4477	T. Aman	Mymensingh (24° 45' 0N, 90° 24' 0E, 16m), Chittagong Hill Tracts (22° 19' 59N, 91° 50' 11E, 6m), Rangpur (25° 45' 0N, 89° 15' 0E, 35m)	Good for Khoi, Muri
9	Pashusail	3990	Boro	Habiganj (24° 22'60N, 91° 25' 0E, 5m)	Aromatic, Tasteful
10	Katarivhogh	4791	T. Amam	Dinajpur (25.63° N, 88.64° E, 34m)	Aromatic, medium slender
11	Chamara	6628	B. Aman	Tangail (24° 15'0N, 89° 55' 0E, 12m), Comilla (23° 27' 28N, 91° 12' 16E, 12m) Chalan Bill	Bold grain, Tasteful, Good for Khoi, Muri
12	Digha	6673	B. Aman	Tangail (24° 15'0N, 89° 55' 0E, 12m), Comilla (23° 27' 28N, 91° 12' 16E, 12m) Chalan Bill	Tasteful, Deep water rice
13	Bashful	3852	T. Aman	Sirajganj (24° 26' 60N, 89° 43' 0E, 12m), Barisal (22° 42' 7N, 90° 22' 16E, 1m)	Aromatic, Tasteful
14	Tulsimala	4870	T. Aman	Mymennsingh (24° 45' 0N, 90° 24' 0E, 16m)	Aromatic, Tasteful

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15	Horkoch	4772	T. Aman	Khulna (22° 36' 0N, 90° 13' 0E, 1m)	Good for Khoi, Muri, Pitha, Polao
16	Birpala	5320	T./B. Aman	Khulna (22° 36' 0N, 90° 13' 0E, 1m)	Tasteful, Submergence tolerant, Good for Muri, Pitha
17	Sadamota	1576	T. Aman	Barisal (22° 42' 7N, 90° 22' 16E, 1m)	Bold grain, Photoperiod sensitive, Submergence tolerant, Good for Muri, Pitha, Insects and disease tolerant
18	Galon	4923	T. Aus	Chittagong Hill Tracts (22° 19' 59N, 91° 50' 11E, 6m)	Bold grain, Jhum rice
19	Radhuni pagal	6711	T. Aman	Rajshahi (24°22' 0N, 88° 35' 60E, 18m)	Aromatic
20	Joina	5315	B. Aman	Khulna (22° 36' 0N, 90° 13' 0E, 1m), Barisal (22° 42' 7N, 90° 22' 16E, 1m)]	Bold grain, Tasteful, Submergence tolerant, Good for Khoi, Muri, Pitha

T. Aman: Transplant Aman rice grown as rainfed, Boro: Irrigated dry season rice, B.Aman: Broadcasted Aman grown as rainfed, T. Aus: Transplant Aus grown as rainfed in upland.

Table 2: Leaf and Ligule characteristics of GI rice

Cultivar name	Leaf characters						Ligule characters			
	BP	BC	LSCA	BLSC	LA	FLA	LiC	LiS	CC	AC
Biruin	intermediate	pale green	absent	green	erect	horizontal	white	2-cleft	pale green	pale green
Kalijira	intermediate	pale green	absent	green	erect	horizontal	white	2-cleft	pale green	pale green
Topa	intermediate	pale green	absent	green	erect	erect	white	2-cleft	pale green	pale green
Begunbichi	intermediate	green	absent	green	erect	horizontal	white	acute to acuminate	pale green	pale green
Chinigura	intermediate	pale green	absent	green	erect	erect	white	2-cleft	pale green	pale green
Balam	intermediate	green	absent	green	erect	erect	white	acute to acuminate	pale green	pale green
Dadkhani	intermediate	pale green	absent	green	erect	erect	white	2-cleft	pale green	pale green
Binni	intermediate	pale green	absent	green	erect	erect	white	2-cleft	pale green	pale green
Pashusail	intermediate	green	absent	green	drooping	erect	white	acute to acuminate	pale green	pale green
Katarivhogh	intermediate	green	absent	green	erect	erect	white	2-cleft	pale green	pale green
Chamara	intermediate	green	present	light purple	drooping	erect	white	2-cleft	pale green	purple

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Digha	intermediate	dark green	absent	green	erect	descending	white	acute to acuminate	pale green	pale green
Bashful	intermediate	green	absent	green	erect	erect	white	2-cleft	pale green	pale green
Tulsimala	intermediate	green	present	light purple	erect	erect	white	2-cleft	pale green	pale green
Horkoch	intermediate	pale green	absent	green	erect	erect	white	2-cleft	pale green	pale green
Birpala	intermediate	pale green	absent	purple lines	droop ing	erect	white	2-cleft	purple	purple
Sadamota	intermediate	green	absent	purple lines	erect	erect	white	2-cleft	pale green	pale green
Galon	intermediate	green	absent	green	erect	erect	white	acute to acuminate	pale green	pale green
Radhuni pagal	intermediate	green	absent	green	droop ing	erect	white	2-cleft	pale green	pale green
Joina	intermediate	pale green	absent	green	erect	erect	white	2-cleft	purple	purple

Legend: BP- Blade pubescence, BC-Blade colour, LSCA-Leaf sheath colour anthocyanin, BLSC-Basal leaf sheath colour, LA-Leaf angle, FLA-Flag leaf angle, LiC-Ligule colour, LiS-Ligule shape, CC-Collar colour, AC-Auricle colour

Table 3: Culm and panicle characteristics of GI rice

Cultivar name	Culm characters				Panicle characters					
	ACN	CA	IC	St	PT	SB	PE	PA	PS	P.Tthr.
Biruin	absent	intermediate	green	intermediate	open	light	well exerted	droopy	low	easy
Kalijira	absent	erect	green	moderately strong	compact	light	well exerted	straight	moderate	easy
Topa	absent	open	green	moderately strong	intermediate	light	well exerted	droopy	moderate	easy
Begunbichi	absent	intermediate	purple lines	strong	compact	light	moderately well exerted	droopy	moderately high	easy
Chinigura	absent	intermediate	light gold	weak	intermediate	light	well exerted	droopy	low	easy
Balam	absent	intermediate	green	strong	open	heavy	well exerted	droopy	moderately high	easy
Dadkhani	absent	procumbent	green	weak	open	light	well exerted	straight	low	easy
Binni	absent	spreading	light gold	intermediate	open	light	moderately well exerted	droopy	moderately high	easy
Pashusail	absent	procumbent	green	weak	open	light	partly exerted	droopy	low	easy
Katarivhogh	absent	erect	green	strong	open	heavy	well exerted	droopy	low	easy

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Chamara	present	spreading	purple line	weak	open	heavy	moderately well exerted	straight	low	easy
Digha	absent	intermediate	light gold	strong	compact	heavy	well exerted	droopy	low	easy
Bashful	absent	erect	green	strong	open	heavy	well exerted	droopy	low	easy
Tulsimala	present	intermediate	purple lines	strong	compact	heavy	well exerted	droopy	low	easy
Horkoch	absent	open	green	strong	intermediate	light	well exerted	droopy	low	easy
Birpala	absent	open	light gold	intermediate	compact	heavy	well exerted	droopy	low	easy
Sadamota	absent	erect	green	strong	intermediate	heavy	well exerted	droopy	low	easy
Galon	absent	intermediate	light gold	strong	compact	light	moderately well exerted	droopy	moderate	easy
Radhuni pagal	absent	spreading	green	weak	intermediate	light	well exerted	droopy	low	easy
Joina	present	open	purple lines	strong	intermediate	heavy	well exerted	droopy	low	easy

Legend: ACN-Anthocyanin colour of nodes, CA-Culm angle, IC-Internode colour, St-Strength, PT-Panicle type, SB-Secondary branching, PE-Panicle exertion, PA-Panicle axis, PS-Panicle shattering, PThr.-Panicle threashability

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Table 4: Grain characteristics of GI rice

Cultivar name	Awn	LA	DA	CA	AC	SC	SE	LPC	LPP	SLC	SLL	SSt	BRS	SCC	TE	DGSc	LS
Biruin	absent	-	-	-	straw	white	low	straw	short hairs	straw	medium	fertile	slender	red	intermediate	Non scented	Early
Kalijira	absent	-	-	-	purple	white	medium	black	short hairs	purple	medium	Highly fertile	Medium	white	intermediate	Scented	Late and slow
Topa	absent	-	-	-	straw	white	medium	Brown furrows on straw	short hairs	straw	medium	Highly fertile	Medium slender	brown	nonglutinous	Non scented	intermediate
Begunbichi	absent	-	-	-	straw	white	medium	straw	Hairs on upper portion	straw	medium	fertile	slender	brown	nonglutinous	Non scented	intermediate
Chinigura	absent	-	-	-	straw	white	medium	straw	short hairs	straw	medium	fertile	Medium slender	white	intermediate	Scented	intermediate
Balam	absent	-	-	-	straw	white	medium	straw	Hairs on upper portion	straw	medium	fertile	slender	red	nonglutinous	Non scented	intermediate
Dadkhani	absent	-	-	-	straw	white	medium	straw	short hairs	straw	medium	fertile	slender	Light brown	nonglutinous	Non scented	Late and slow
Binni	absent	-	-	-	straw	white	medium	Brown furrows on straw	short hairs	straw	long	fertile	slender	brown	intermediate	Non scented	Early and fast
Pashusail	present	medium	Whole length	straw	brown	white	medium	gold	short hairs	straw	medium	fertile	slender	red	nonglutinous	Non scented	Early and fast
Katarivhogh	present	short	Tip only	straw	brown	white	few	gold	short hairs	straw	medium	fertile	slender	red	intermediate	Non scented	intermediate
Chamara	present	Very long	Whole length	straw	purple	purple	medium	straw	short hairs	straw	long	Highly fertile	slender	red	nonglutinous	Non scented	intermediate

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Digha	absent	-	-	-	straw	white	medium	straw	short hairs	straw	medium	Partly sterile	slender	brown	nonglutinous	Non scented	Early and fast
Bashful	present	short	Tip only	straw	straw	white	low	Brown furrows on straw	short hairs	straw	long	Highly fertile	slender	white	nonglutinous	Non scented	Late and slow
Tulsimala	absent	-	-	-	purple	purple	high	Reddish to light purple	short hairs	purple	medium	Highly fertile	slender	white	nonglutinous	Non scented	intermediate
Horkoch	absent	-	-	-	brown	white	medium	straw	short hairs	red	long	Highly sterile	Medium slender	white	nonglutinous	Non scented	Early and fast
Birpala	present	short	Tip only	straw	purple	purple	low	Brown spots on straw	short hairs	straw	medium	fertile	Medium slender	Light brown	intermediate	Non scented	intermediate
Sadamota	absent	-	-	-	straw	white	low	Brown spots on straw	short hairs	straw	long	fertile	Medium slender	white	intermediate	Non scented	Late and slow
Galon	absent	-	-	-	straw	white	medium	straw	Hairs on upper portion	straw	short	fertile	slender	white	nonglutinous	Non scented	intermediate
Radhuni pagal	absent	-	-	-	brown	white	medium	black	short hairs	straw	long	Partly sterile	Medium slender	white	nonglutinous	Scented	Early and fast
Joina	present	Very short	Tip only	purple	purple	purple	medium	Brown furrows on straw	short hairs	straw	long	Highly fertile	Medium slender	Light brown	intermediate	Non scented	intermediate

Legend: LA-Length of longest awn, DA-Distribution of awn, CA-Colour of awn, AC-Apiculus colour, SC-Stigma colour, SE-Stigma exertion, LPC-Lemma and palea colour, LPP-Lemma and palea pubescence, SLC-Sterile lemma colour, SLL-Sterile lemma length, SSt-Spikelet sterility, BRS-Brown rice shape, SCC-Seed coat colour, TE-Endosperm type, DGSc-Decorticated grain scent, LS-Leaf senescence

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Table 5: Quantitative characteristics of 20 GI rice

Cultivar name	LL(cm)	LW(cm)	LiL(mm)	CL (cm)	TT (no.)	CD (mm)	PL (cm)	ET (no.)	HD (days)	TGW (g)	GL (mm)	GW (mm)	BRL (mm)	BRW (mm)	DM (days)	Y/H (g)
Biruin	40.6	0.92	12.8	102.6	22	3.61	26.2	18	91	19.0	8.34	1.9	6.5	1.68	120	16.49
Kalijira	47.0	0.94	16.2	103.2	14	3.77	25.6	13	99	19.2	6.45	1.89	4.28	1.67	127	9.53
Topa	50.6	1.02	15.2	95	17	3.70	26.6	15	92	27.0	8.36	2.28	6.46	2.19	121	8.40
Begunbichi	51.0	0.80	11.4	79	7	3.67	21.0	6	85	20.2	7.91	2.01	5.05	1.65	115	7.05
Chinigura	47.6	0.94	12.2	99.2	15	3.69	26.0	13	92	11.9	7.12	1.91	4.93	1.68	122	6.38
Balam	53.0	1.50	11.6	102	7	5.45	28.0	6	98	21.4	8.63	1.92	5.91	1.67	125	14.35
Dadkhani	48.4	0.94	13.0	72	9	4.11	22.4	8	92	16.6	8.83	1.73	6.21	1.55	120	7.79
Binni	52.0	0.98	17.4	72	12	4.66	23.6	10	91	24.6	9.54	1.94	6.67	1.71	120	7.79
Pashusail	72.4	0.84	16.6	128.6	13	6.18	26.4	12	159	18.4	8.86	1.89	6.32	1.68	188	20.93
Katarivhogh	41.2	0.82	18.2	97.4	8	3.32	25.6	8	97	17.1	9.22	1.82	6.74	1.68	125	8.41
Chamara	45.8	1.22	15.8	109.6	11	4.31	25.4	10	87	24.2	8.36	2.42	6.33	1.87	116	6.38
Digha	57.2	1.3	15.2	102.6	10	4.99	28.4	8	141	25.4	7.92	2.06	8.12	2.15	169	16.76
Bashful	57.2	1.1	17.0	82.2	8	4.52	28.4	7	102	19.7	8.39	1.77	6.05	1.55	130	7.51
Tulsimala	42.6	0.82	14.4	91.2	10	3.84	22.4	9	91	11.9	6.57	1.63	4.51	1.48	121	7.47
Horkoch	58.6	1.04	18.2	91.2	6	5.20	27.0	5	106	32	8.12	2.23	5.81	2.04	134	10.98
Birpala	42.6	1.06	17.8	98.2	16	4.54	22.4	14	94	23.6	7.84	2.01	5.50	1.84	123	9.78
Sadamota	48.8	0.92	17.6	96.2	10	4.39	24.6	9	98	23.1	8.3	2.31	6.25	2.36	126	6.96
Galon	56.0	1.40	11.6	104.0	5	4.46	25.0	5	98	20.09	7.37	1.85	5.43	1.74	127	15.12
Radhuni pagal	47.2	0.94	14.8	107.0	10	3.75	27.0	6	106	32	8.12	2.23	5.81	2.04	130	12.00
Joina	44.2	0.92	17.4	97.2	11	4.31	24.4	9	99	23.9	7.83	2.1	5.51	1.89	128	11.35
Mean	50.20	1.02	15.22	96.52	11.05	4.32	25.32	9.55	100.90	21.56	8.10	2.00	5.92	1.81	129.35	10.57
Standard Deviation	7.55	0.19	2.38	13.18	4.17	0.72	2.11	3.59	17.93	5.39	0.79	0.21	0.87	0.24	17.74	4.13
CV(%)	15.03	19.06	15.62	13.65	37.77	16.60	8.33	37.60	22.90	24.97	9.72	10.53	14.63	13.14	13.71	39.10
Standard error	1.69	0.04	0.53	2.95	0.93	0.16	0.47	0.80	4.01	1.20	0.18	0.05	0.19	0.05	3.97	0.92
LSD (0.05)	3.31	0.09	1.04	5.78	1.83	0.31	0.93	1.57	10.28	2.36	0.35	0.09	0.38	0.10	7.77	1.81

Legend: LL-Leaf length, LW-Leaf width, LiL-Ligule length, CL-Culm length, TT-Total tiller, CD-Culm Diameter, PL-Panicle length, ET-Effective tiller, HD-Heading days/50% flowering, TGW-Thousand grain weight, GL-Grain length, GW-Grain width, BRL-Brown rice length, BRW-Brown rice width, DM-Days to Maturity, Y/H-Yield per hill

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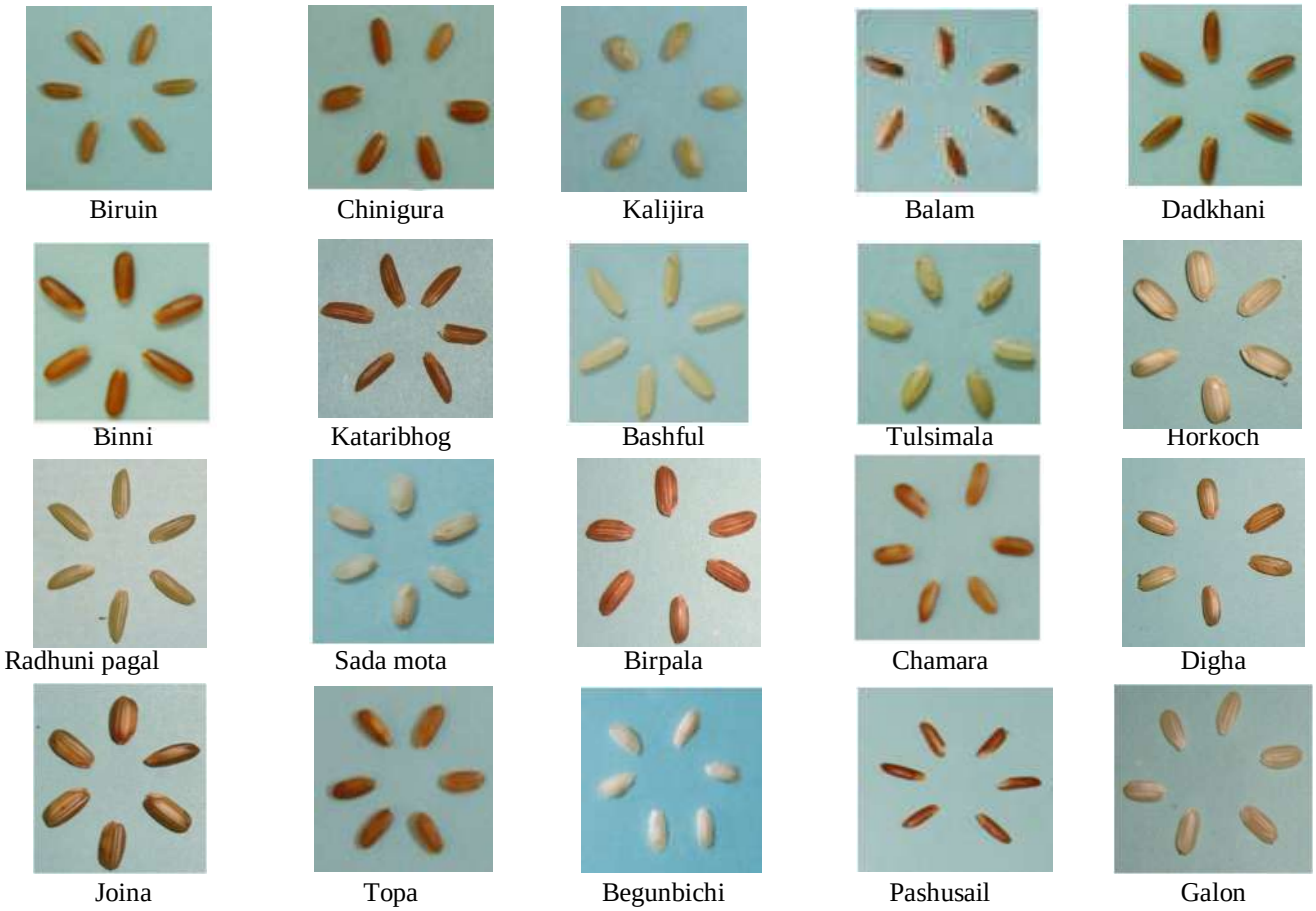

Figure 1. Photographs showing the distinctness in brown rice of 20 GI rice grown in Bangladesh

6. Conflict of Interest:

The authors declare that they have no conflicts of interest concerning this article.

7. Acknowledgement:

The authors are grateful to Coordinated sub-project on "Characterization of important plant genetic resources" supported by World Bank through the NATP-SPGR, Bangladesh Agricultural Research Council for providing funds for this research.

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