

## GENETIC DIVERSITY OF GRAIN QUALITY CHARACTERS IN BANGLADESH RICE GERMPLASM

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**Abstract:** Grain quality characters of 575 Bangladesh rice cultivars from 7 ecotypes were studied. The cultivars were collected from 6 distinct regions (Rajshahi, Dhaka, Sylhet, Barisal, Khulna and Chittagong) of the country. Significant variation was observed in all the parameters investigated. The range of grain length, width, thickness and weight of 100 grains varied between 5.26 mm and 10.36 mm, 1.76 mm and 3.68 mm, 1.30 mm and 2.54 mm, and between 0.84 g and 3.68 g, respectively. Long grains (7.76-9.00 mm) were found to be present in a maximum number of cultivars. However, based on length/width ratio (grain shape), medium grains (L/W ratio 2.10-3.00) showed the maximum frequency. Grain quality characters varied widely according to ecotypes. The cultivars of Transplanted Aman (T. Aman) ecotype exhibited the highest level of genetic variation. Geographical distribution of grain quality parameters differed according to the regions. Cultivars collected from Khulna region were more diverse than cultivars collected from other regions.

**Key words:** Bangladesh rice; ecotype; genetic diversity; grain quality.

### Introduction

Quality of rice grain has been an important factor in rice production. Some of the key components of rice quality are milling quality, grain size, shape and appearance, cooking, eating and processing, nutritive, etc. of the grain (Juliano, 1979; Webb, 1985; Cruz and Khush, 2000). Physical properties of the rice grain are size and shape, head rice and translucency, traditionally have been integral objectives of national rice breeding programs (Juliano and Duff, 1991). Consumers have definite preferences for milled rice size and shape based on the cooked rice texture they prefer (Juliano, 1985). Thus, grain size and shape are the first criteria of rice quality that breeders consider in developing new varieties to release in commercial production.

Rice grains may be classified into grain-type categories based upon three physical characteristics, that is, length, shape and weight (Webb, 1985). Genotypic variation in grain length, grain breadth and grain length/breadth ratio has been reported in USA rice varieties (Adair *et al.*, 1973; Webb *et al.*, 1979; Webb *et al.*, 1985). Islam (1990) carried out ecological and morphological studies on 491 deepwater rice (DWR) varieties from Bangladesh and found a wide variation in grain quality characteristics i.e., in hull color, pericarp color, length/width ratio and grain weight. Kaul *et al.* (1978) reported that length/breadth ratio of 54 local and 6 improved cultivars from Bangladesh ranged between 1.75 and 4.07 with the mean value of 2.47. Pathan *et al.* (1993) reported that grain weight of 26 rice cultivars released by BIRRI varied from 12.9 g to 28.1 g/1000 grains. Lahiri *et al.* (1993) observed that the length, breadth, length/breadth ratio and 100-grain weight of 4 induced rice mutants ranged from 4.75-7.10 mm, 2.20-2.70 mm, 2.39-2.89 and 1.41-2.47 g, respectively. Literature suggests that grain quality studies received very little attention in the past (Juliano and Duff, 1991). The relationship between grain characters and growing zones and the ecotypic distribution of grain characters remained untouched too. Under the given context, especially in Bangladesh, grain quality improvement becomes an important breeding objective in the national research programs.

The aims of this study were therefore- (i) to assess the extent of variation in grain quality characteristics of Bangladesh rice cultivars; (ii) to determine relationships, if any, between quality characters and ecotypes; and also (iii) to investigate whether the observed genetic variation in grain quality characters had any relation with geographical (regional) distribution within the country.

### Materials and Methods

**Materials:** Five hundred and seventy five Bangladesh rice cultivars representing 7 ecotypes, preserved in the Plant Genetics Laboratory of Kyushu University, Japan were used in the study. The sampling places of the cultivars and their corresponding ecotypes are shown in Table 1. The seed samples were collected from 7 regions during 1990-91 by a joint group of Bangladeshi-Japanese Researchers. All of the cultivars were grown at the Kyushu University Farm, Kyushu University, Japan during 2000-2003.

**Methods:** Measurements were done for length, width and thickness of husked grains, using five grains of each cultivar. Measurements were done at the largest position of the respective characters. Moreover, of the husked grains, calculations were done on the ratio of 'length to width' using average value of the respective

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characters. Well-matured, sun dried husked grains were weighed on a precision balance to obtain 100 grain weight. The cultivars were grouped based on the mean values. Standard deviations of each cultivar were also determined for all the parameters studied. Correlation coefficients among grain length, grain width, grain thickness as well as between grain weight, grain length, grain width, grain thickness and L/W ratios of husked grains were estimated to make relationship among the grain characters. All the seed samples (n = 575) were employed to calculate the correlation coefficient values. The correlation coefficients were subjected to t-test to determine the level of significance at 573 (i.e. n-2) df.

Table 1. Distribution of rice cultivars according to ecotypes and geographical regions in Bangladesh

Region	Ecotype							Total Cultivars
	Aus	T. Aman	B. Aman	DWR	Boro	All Season	Unknown	
Rajshahi	14	97	7	4	0	0	0	122
Dhaka	3	58	6	0	0	1	0	68
Sylhet	6	20	8	0	23	2	0	59
Barisal	0	82	0	0	0	0	0	82
Khulna	0	113	2	2	1	0	0	118
Chittagong	0	117	0	3	0	0	0	120
Unknown	0	0	0	0	1	0	5	6
<b>Total</b>	<b>23</b>	<b>487</b>	<b>23</b>	<b>9</b>	<b>25</b>	<b>3</b>	<b>5</b>	<b>575</b>

## Results

*Grain length variation:* Length of grains was found between 5.26 mm and 10.36 mm with an average value 7.94 mm. The standard deviations of each cultivar were recorded to be between 0.05 and 0.89. Based on length, the grains were grouped into different grain size classes according to the classification by Jennings *et al.* (1979) as extra long (> 9.00 mm), long (7.76-9.00 mm), medium (6.51-7.75 mm) and short (5.26-6.50 mm). All of the grain length classes were found in cultivars of T. Aman, B. Aman and Boro ecotypes (Table 2). Extra long grains were absent in DWR and Unknown ecotype cultivars, while Aus and All Seasons ecotypes had only long and medium grains. These results imply that T. Aman, B. Aman and Boro ecotype cultivars are more diverse than other ecotypes in grain length. Our results are also supported by Uddin (1993) in varietal characters including grain size and shape (Sharma *et al.*, 1997), and in RAPD markers (Parsons *et al.*, 1999).

We also examined the geographical distribution of grain length variation among rice cultivars studied (Table 2). Length of grains varied significantly among different regions. However, the magnitude of variation was less prominent in case of long and medium grains. Grain length variation was more evenly distributed in Khulna region as compared to other regions suggesting that Khulna region may act as an area for further germplasm collection.

*Grain width variation:* Grain width ranged between 1.76 mm and 3.68 mm with an average value 2.73 mm. The standard deviation of each cultivar was noted between 0.04 and 0.43. Based on the width, the grains were classified into three groups, i.e. 1.75-2.50 mm, 2.50-3.25 mm and larger than 3.25 mm. Aus and T. Aman ecotypes contained all of the width groups (Table 3). B. Aman, Boro and DWR ecotypes contained grains from 1.75-2.50 mm and 2.50-3.25 mm groups. This result suggests that cultivars from Aus and T. Aman ecotypes are rich in grain width variation.

Grain width varied widely according to geographical regions (Table 3). Chittagong region showed a significantly higher proportion of grains from 1.75-2.50 mm group. Khulna region had a higher number of cultivars in > 3.25 mm group, while Sylhet region had no cultivar from > 3.25 mm group. Barisal, Chittagong, Dhaka and Rajshahi regions possessed almost equal number of cultivars from the > 3.25 mm group. Grain width variation showed more even distribution in Khulna region, implying that Khulna region contained diverse sizes of grains and acts an area for future germplasm collection.

*Grain thickness variation:* Thickness of grains was observed between 1.30 mm and 2.54 mm with an average 1.91 mm. The standard deviation of each cultivar was found to be between 0.04 and 0.32. Rice cultivars were classified on the basis of thickness as 1.30-1.70 mm, 1.70-2.10 mm, and larger than 2.10 mm groups. The 1.70-2.10 mm group contained the maximum number of cultivars denoting that cultivars having the thickness of 1.70-2.10 mm are grown widely in Bangladesh.

The ecotypic distribution of grain thickness variation is shown in Table 4. Proportion of grain thickness variation was almost equal in Aus and T. Aman ecotypes. Boro ecotype contained nearly equal number of cultivars in 1.30 to 1.70 mm and 1.70 to 2.10 mm groups. B. Aman and DWR ecotypes showed equal number of cultivars in 1.30 to 1.70 mm group although they differed in total number of cultivars.

Table 2. Ecotypic and geographical distribution of grain length variation in Bangladesh rice cultivars

** Grain Size	Ecotype							* Region							Total
	Aus	T. Aman	B. Aman	DWR	Boro	All Season	Unknown	Rajshahi	Dhaka	Sylhet	Barisal	Khulna	Chittagong	Unknown	
Extra long	0	56	3	0	2	0	0	8 (6.50)	2 (2.94)	6 (10.10)	15 (18.29)	22 (17.88)	8 (6.67)	0 (0.00)	<b>61</b>
Long	13	261	14	7	11	1	3	66 (54.09)	39 (57.35)	29 (49.15)	48 (58.53)	56 (45.52)	69 (57.50)	3 (50.00)	<b>310</b>
Medium	10	126	4	1	9	2	1	38 (31.15)	23 (33.80)	17 (28.81)	14 (17.07)	29 (23.57)	30 (25.00)	2 (33.33)	<b>153</b>
Short	0	44	2	1	3	0	1	10 (8.20)	4 (5.88)	7 (11.86)	5 (6.10)	11 (8.94)	13 (10.83)	1 (16.67)	<b>51</b>
<b>Total</b>	<b>23</b>	<b>487</b>	<b>23</b>	<b>9</b>	<b>25</b>	<b>3</b>	<b>5</b>	<b>122</b>	<b>68</b>	<b>59</b>	<b>82</b>	<b>118</b>	<b>120</b>	<b>6</b>	<b>575</b>

\* The numbers in the parentheses indicate percentage

\*\* Grain size Length (mm)  
 Extra long > 9.00  
 Long 7.76-9.00  
 Medium 6.51-7.75  
 Short 5.26-6.50

Table 3. Ecotypic and geographical distribution of grain width variation in Bangladesh rice cultivars

Grain Width (mm)	Ecotype							* Region							Total
	Aus	T. Aman	B. Aman	DWR	Boro	All Season	Unknown	Rajshahi	Dhaka	Sylhet	Barisal	Khulna	Chittagong	Unknown	
1.75-2.50	6	153	2	1	10	0	0	32 (26.22)	18 (26.47)	18 (30.51)	27 (32.93)	33 (27.11)	43 (35.83)	1 (16.67)	<b>172</b>
2.50-3.25	15	303	21	8	15	3	4	84 (68.85)	47 (69.12)	41 (69.49)	50 (60.97)	70 (59.32)	73 (60.83)	4 (67.66)	<b>369</b>
> 3.25	2	31	0	0	0	0	1	6 (4.92)	3 (4.41)	0 (0.00)	5 (6.10)	15 (12.71)	4 (3.33)	1 (16.67)	<b>34</b>
<b>Total</b>	<b>23</b>	<b>487</b>	<b>23</b>	<b>9</b>	<b>25</b>	<b>3</b>	<b>5</b>	<b>122</b>	<b>68</b>	<b>59</b>	<b>82</b>	<b>118</b>	<b>120</b>	<b>6</b>	<b>575</b>

\* The numbers in the parentheses indicate percentage



Grain thickness also differed according to regions (Table 4). The number of cultivars from 1.30-1.70 mm group was remarkably different in Rajshahi, Khulna and Chittagong region though the three regions had nearly equal number of cultivars. In addition, Chittagong region had a significantly lower number of cultivars with thickness larger than 2.10 mm than other regions. Cultivars from Dhaka and Barisal region exhibited an identical variation pattern in grain thickness. Like grain length, grain thickness variation was distributed more evenly in Khulna region.

*Relationships among grain length, grain width and grain thickness:* To establish relationships among length, width and thickness of the husked grains, correlation coefficients among them were calculated. The correlation coefficient between length and width of husked grains were obtained to be 0.37, which is significant at 0.1% level of probability as determined by t-test. The correlation coefficient between length and thickness of husked grains was ascertained to be 0.42, showing positive correlation at 0.1% level of probability. The correlation coefficient between width and thickness of husked grains was noted to be 0.80, showing significant correlation between them at 0.1% level of probability.

*Length/width ratio:* Ratios of grain length to grain width were observed between 1.91 and 4.88 with an average value 2.95. Based on length/width (L/W) ratios, Bangladesh rice cultivars were classified into shape groups as bold (L/W ratio 1.10-2.00), medium (L/W ratio 2.00-3.00) and slender (L/W ratio > 3.00) according to the classification of Jennings *et al.* (1979). Medium shaped grains were found in a maximum number of cultivars followed by the slender group. Round grain (L/W ratio 1.00 or less) was absent, while the grains of 6 cultivars showed bold shape. T. Aman, Boro and Unknown ecotypes contained grains from all of the shape classes, while other ecotypes had only medium and slender grains (Table 5). No significant variation was found among ecotypes regarding the number of cultivars for medium and short grains, except T. Aman ecotype contained a slightly higher percentage of slender grains.

When the distribution of grain shape variation in different regions was investigated, the proportion of the distribution was found to be different among the regions (Table 5). Sylhet, Khulna and Chittagong regions showed all types of grain shape variations. The Rajshahi region had cultivars only with medium shapes. The proportion of medium and slender grains was almost same among the regions except for Rajshahi region.

*Variation of grain weight:* The 100-grain weight varied from 0.84 g to 3.68 g among the total cultivars. In all of the ecotypes, group with 1.75-2.75 g was the larger in number followed by group with 0.75-1.75 g (Table 6). However, grains of 0.75-1.75 g group represented slightly higher percentage in Aus and T. Aman ecotypes than B. Aman, Boro and other ecotypes.

Grain weight variation was different according to regions (Table 6). Proportion of cultivars in 0.75-1.75 g and 1.75-2.75 g groups was analogous in Dhaka, Sylhet and Barisal regions. Barisal and Khulna region contained a higher number of cultivars having weights more than 2.75 g. Like grain length, grain width and grain thickness, grain weight variation was also more evenly distributed in Khulna region.

*Relationships among grain weight, length, width, and thickness and L/W ratio:* To study relationships among grain weight, grain length, grain width, grain thickness and L/W ratios of husked grains, correlation coefficients among the grain characters were calculated. The correlation coefficient between weight and length of husked grains was found 0.71, which was significant at 0.1% probability level. The correlation coefficient between weight and width of husked grains was found 0.78, showing positive correlation at 0.1% probability level. The correlation coefficient between weight and thickness of husked grains was found to be 0.77, showing significant correlation between them at 0.1% level of probability. The correlation coefficient between weight and L/W ratio of husked grains was calculated to be -0.14, showing a negative correlation between the measured characters at 0.1% level.

## Discussion and Conclusion

A wide variation was observed in all the grain characters of Bangladesh rice cultivars investigated in the present study. Long grains (7.76-9.00 mm) were found in maximum number of cultivars followed by medium ones. However, based on length/width ratio (grain shape), medium grains (L/W ratio 2.10-3.00) showed the maximum frequency, which was followed by the slender ones. This result suggests that preference for long and medium grains. However, it was reported that the people of Bangladesh like long, slender and shiny grains (Choudhury *et al.*, 1989; Unnevehr *et al.*, 1992).

In the present study, grain quality characters were found to vary significantly according to ecotypes. T. Aman ecotype contained diverse set of grains possessing all the variations of grain quality characters, implying that cultivars from T. Aman ecotype provide a rich source of genetic diversity. Our results are also supported by the findings of Glaszmann (1987). Variations observed in other ecotypes are not conclusive as sample sizes are small. In the future, investigations of these ecotypes should be made using a greater number of samples



Table 4. Ecotypic and geographical distribution of grain thickness variation in Bangladesh rice cultivars

Grain Thickness (mm)	Ecotype							* Region							Total
	Aus	T. Aman	B. Aman	DWR	Boro	All Season	Unknown	Rajshahi	Dhaka	Sylhet	Barisal	Khulna	Chittagong	Unknown	
1.30-1.70	3	81	1	1	10	0	0	11 (9.01)	9 (13.22)	13 (22.09)	11 (13.41)	20 (16.94)	31 (25.83)	1 (16.66)	<b>61</b>
1.70-2.10	16	329	18	6	11	3	5	86 (70.49)	51 (74.52)	37 (62.70)	58 (70.73)	71 (60.17)	80 (66.67)	5 (83.33)	<b>310</b>
> 2.10	4	77	4	2	4	0	0	25 (20.49)	8 (11.26)	9 (15.22)	13 (15.85)	27 (22.88)	9 (7.50)	0 (0.00)	<b>153</b>
<b>Total</b>	<b>23</b>	<b>487</b>	<b>23</b>	<b>9</b>	<b>25</b>	<b>3</b>	<b>5</b>	<b>122</b>	<b>68</b>	<b>59</b>	<b>82</b>	<b>118</b>	<b>120</b>	<b>6</b>	<b>575</b>

\*The numbers in the parentheses indicate percentage

Table 5. Ecotypic and geographical distribution of grain shape variation in Bangladesh rice cultivars

*Grain Shape	Ecotype							Region							Total
	Aus	T. Aman	B. Aman	DWR	Boro	All Season	Unknown	Rajshahi	Dhaka	Sylhet	Barisal	Khulna	Chittagong	Unknown	
Bold	0	3	0	0	2	0	1	0	0	2	0	2	1	1	<b>6</b>
Medium	15	329	17	7	14	3	2	122	48	34	42	71	68	2	<b>387</b>
Slender	8	155	6	2	9	0	2	0	20	23	40	45	51	3	<b>182</b>
<b>Total</b>	<b>23</b>	<b>487</b>	<b>23</b>	<b>9</b>	<b>25</b>	<b>3</b>	<b>5</b>	<b>122</b>	<b>68</b>	<b>59</b>	<b>82</b>	<b>118</b>	<b>120</b>	<b>6</b>	<b>575</b>

\*\*Grain Shape L/W ratio  
 Bold 1.10-2.00  
 Medium 2.10-3.00  
 Slender > 3.00

Table 6. Ecotypic and geographical distribution of grain weight variation in Bangladesh rice cultivars

Grain Weight (g)	Ecotype							* Region							Total
	Aus	T. Aman	B. Aman	DWR	Boro	All Season	Unknown	Rajshahi	Dhaka	Sylhet	Barisal	Khulna	Chittagong	Unknown	
0.75-1.75	9	121	3	1	5	1	1	28 (22.95)	14 (20.58)	15 (25.42)	16 (19.51)	31 (26.27)	35 (28.46)	2 (33.33)	<b>141</b>
1.75-2.75	12	305	19	8	19	2	3	84 (68.85)	49 (72.05)	40 (67.79)	53 (64.63)	64 (54.24)	75 (60.97)	3 (50.00)	<b>368</b>
> 2.75	2	61	1	0	1	0	1	10 (8.19)	5 (7.35)	4 (6.77)	13 (15.85)	23 (19.49)	13 (10.57)	1 (16.67)	<b>66</b>
<b>Total</b>	<b>23</b>	<b>487</b>	<b>23</b>	<b>9</b>	<b>25</b>	<b>3</b>	<b>5</b>	<b>122</b>	<b>68</b>	<b>59</b>	<b>82</b>	<b>118</b>	<b>120</b>	<b>6</b>	<b>575</b>

\*The numbers in the parentheses indicate percentage



Grain quality characters also varied widely according to regions. Cultivars collected from Khulna region exhibited the highest degree of variability indicating Khulna region as a 'hotspot' and can be targeting region for further sampling required for species conservation. Parsons *et al.* (1999) reported that Central Bangladesh (Dhaka and Barisal regions in this study) had the highest level of diversity as detected by RAPD markers. However, our present results are in contradiction with their findings. But then, as the diversity levels were obtained from different materials using different methodology, it is not possible to draw precise comparison of the diversity of grain quality characters in this study with those of the other studies.

Correlation coefficients of grain length and grain width, grain length to grain thickness and grain width to grain thickness of husked grains were calculated as 0.37, 0.42 and 0.80, respectively, suggesting that a positive correlation exists among them. Satoh *et al.* (1990a, 1990b) also found positive correlation among length, width and thickness of husked grains in cultivars collected from some African countries. Grain weight was found to be positively correlated with grain length, grain width and grain thickness but negatively correlated with L/W ratio in the present study. Choudhury *et al.* (1979) also reported similar relationship in some Bangladesh rice cultivars.

Preferences for grain size and shape vary from one group of consumers to the other. In general, long grains are preferred in the Indian sub-continent (Cruz and Khush, 2000). Adair *et al.* (1973) studied the US rice in details and reported that the short and medium grain types are generally sticky, soft and viscous, while the long grain type is non-sticky and hard. Webb *et al.* (1979 and 1985) also noticed a particular trend of grain cooking quality characters related to grain shape. The size groups differed in amylose content, alkali digestion, gelatinization temperature, water absorption and taste. However, such association of character is not always present among rice cultivars in the world, as there exist in long grain glutinous type, as well as floating, large grain cultivars with high amylose contents (Sato, 1997). Therefore, it is imperative to investigate whether there exist in any relationship between quantitative and qualitative characters in Bangladesh rice cultivars.

In Bangladesh rice research on grain quality was initially overshadowed by the need for higher yields, and disease and pest resistance. Food self-sufficiency for an expanding population was necessarily the primary goal. However, self-sufficiency in rice production renewed interest in grain quality in national research programs. Large variability is known to exist in Bangladesh rice germplasm. However, due to the neglect and overemphasis on yield increases most of them are already lost and many are at the verge of extinction. Hence, the evaluation of Bangladesh local rice cultivars for grain quality characters holds utmost importance. The variations of grain quality characters obtained in Bangladesh rice cultivars can be regarded as useful materials, which can be exploited through breeding.

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