Grain Appearance Quality of Parental and F_2 Segregating Populations of Aus Rice (*Oryza sativa* L.)

Abstract

Longer grain length with smaller grain breadth, length-breadth ratio and 1000-grain weight is considered desirable character for the development of fine grain premium quality rice. In the present experiment, grain appearance quality of 15 F_2 families and 10 parental genotypes were determined to select fine grain rice. The maximum mean value for thousand seed weight was found from the genotypes P2 (29.32g), P1 (28.89g), and F_2 generations of P2 x P5 (32.77g), P2 x P1 (27.30g), P1 x P4 (26.04g) and were considered as high yielders in terms of grain weight. The highest mean values for grain length were found from the genotypes P6 (9.95 mm; grain breadth 2.23 mm), P7 (9.36 mm; grain breadth 2.62 mm), and F_2 generations of P6 x P7 (9.46 mm; grain breadth 2.44 mm), P3 x P6 (9.40 mm; grain breadth 2.18 mm), P7 x P6 (9.37 mm; grain breadth 2.29 mm), P7 x P3 (9.36 mm; grain breadth 2.33 mm). The F_2 progenies of the cross P1 x P4 (7.79 to 11.61 mm) and P6 x P3 (7.69 to 11.11 mm) showed extremes performance for grain length indicating transgressive segregation for this trait. The superior genotypes with desirable grain characters could be selected from transgressive segregation of F_2 families for the development of new varieties of fine grain rice.

Keywords: Fine grain rice, length-breadth ratio, grain size, slender grain, premium quality, yield.

Introduction

Rice is the staple food in the country and is grown on 75% of the total cultivated land, constituting 90% of the total food grain production (BBS, 2022). Bangladesh was the fourth largest rice producer in the world and average rice production during 2017-2018 was more than 53 million tones but its productivity was low compared to other Asian countries, such as China, India and Indonesia (FAOSTAT, 2022). Rice production must be increased to keep pace with population growth as population is increasing at an alarming rate in Asian countries. Considering the importance of rice, the most important global and national perspectives is to increase the rice production.

Grain appearance, one of the key determinants of rice quality along with yield because it is the prime benchmark of rice breeding to meet consumer's demand (Lang *et al.*, 2013; Sultana *et al.*, 2022). Functional quality of rice may be considered from the point of view of size, shape and appearance of the grain, milling quality, cooking properties and nutritional contents (Bhonsle and Sellappan, 2010). Head rice recovery is one of the important milling properties and yield of head rice vary depending on many factors (Adair *et al*., 1973). The rice millers prefer varieties with high milling and head rice out turn. On the other hand, consumers prefer the size, shape and physicochemical qualities of rice (Merca and Juliano, 1981). Grain quality has the ability to attract consumers, and is characterized by grain shape, size, color and other physiochemical properties. Size and shape are important to consumers preference and vary from one group of consumers to another (Khush *et al.*, 1979; Khush, 2013). High income group of people in Bangladesh prefer long slender grain, whereas lower income group prefer bold grain (Anonymous, 1997). Milled rice was first classified into three categories based on length, long (>6.0 mm in length), medium (5-6 mm in length) and short (<5.0 mm in length). They were again classified into three classes according to the length/breadth (L/B) ratio; slender (ratio more than 3.0); bold (ratio 2.0-3.0), round (ratio <2.0) to determine size and shape (Hosen *et al.* 2016). The information on the grain quality of rice varieties is still scarce in Bangladesh. There may be some special grain characteristics to be essential for future rice breeding program. From that point of view the present study was undertaken to find out the grain quality parameters of parental and segregating families of Aus rice.

Materials and Methods

The research work was conducted at the experimental field, Department of Genetics and Plant Breeding, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during Aus season of 2018. The 15 F_2 populations along with 10 parental genotypes of Aus rice were evaluated in a Randomized Complete Block Design (RCBD) experiment with three replications to study the grain quality. Pre-germinated seeds of the experimental materials were sown in well prepared nursery bed for quick germination and seedling production. After field preparation, 25 days old seedlings were transplanted at the spacing of 20 cm × 20 cm. Basal fertilizers was applied during land preparation @ 60, 75, and 45 kg per ha, TSP, MoP and gypsum, respectively and urea was applied @ 180 kg per ha at 12 and 25 days after transplanting following BRRI recommendation (Anonymous, 2018). The crop was harvested at maturity, when 90% of the seeds became golden yellow color and plants of each genotype in three different replications were separately bundled, properly tagged and then brought to the threshing floor, and were threshed separately. Data were recorded on panicle length, grain number in panicle, grain color, grain shape, grain length (GLT), grain breadth (GBD), 1000-grain weight (TSW), and length-breadth ratio (L/B ratio) of rice grain (Dela and Khush, 2000). Analysis of variance (ANOVA), mean, standard error (SE) and coefficient of variation (CV) were done from the replicated data of different characters by using computer software 'STAR' (Statistical Tools for Agricultural Research).

Results and Discussion

Mean performance, standard deviation and coefficient of variations for panicle length, grain number in panicle, filled grain number, empty grain number, grain length (mm), grain breadth (mm), and 1000-grain weight (g) of rice grain are presented in **Table 1** and **Table 2**. Appearance quality parameters such as grain color, grain size, grain shape, grain length, grain breadth and grain length-breadth ratio are presented in **Table 3**. Variations among parental genotypes and F_2 populations for panicle length, number of grains per panicle, grain color, grain shape observed in parental genotypes and F_2 segregating populations are presented in **Figure 1 and Figure 2 (A&B)**.

Rice yield is very complex and determined by multiplicative factors including panicle length, panicle number per plant, number of grains per panicle, number of filled grains and grain weight (Rafii et al., 2014; Li *et al.*, 2021). Generally, long panicles contain a greater number of grains compare to short panicle. The highest mean values for panicle length were found from the parental genotypes P7 (27.30 cm), P6 (25.07 cm), and the F_2 generations of P7 x P3 (26.70 cm), P3 x P4 (25.64 cm), P3 x P7 (25.48 cm) and P7 x P6 (25.24 cm). The genotype with the highest mean value for number of filled grains per panicle and minimum numbers of empty grains is considered as better genotype which leads to higher yield per plant. The highest filled grain was found from the parental genotypes P3 (143.38; empty grain 24.68), P7 (118.99; empty grain 35.68), P6 (111.42; empty grain 28.95), and from F_2 generations of P7 x P6 (116.57; empty grain 21.74), P4 x P6 (110.80; empty grain 26.29), P3 x P4 (106.93; empty grain 46.86). The F_2 progenies of the cross P7 x P6 showed extremes performance for number of filled grains per panicle (17.2 to 237.6), indicating transgressive segregation for this trait in this populations (**Table 1**). The results indicated that several genes are involved in the genetic control of the number of filled grains per panicle. Premkumar (2012) also reported transgressive segregations for grain quality traits in rice.

Grain color, grain shape, grain size and grain weight are the important appearance quality traits of rice as they are affecting quality of rice (Sultana *et al.*, 2022). Estimation of appearance quality traits of rice is essential for rice breeding. Variation in appearance quality was measured in this study by observing grain color, grain shape and estimating grain size and grain weight in parental (**Figure 1**) as well as F_2 populations of rice (**Figure 2A and 2B**). Results of six appearance quality parameters, grain color, grain shape, grain breadth (B), grain length (L), L/B ratio, and 1000-grain weight (TGW) were measured in 15 F_2 populations and 10 parents (**Table 2 and Table 3**). All the measurements were performed based on rice descriptor (Rice Descriptor, IRRI). There were no significant differences between the parental lines for grain color (all golden) except P3 (red grain color) but significant differences were observed among the segregating (F_2) populations. Variations were observed for grain size, shape and length-breadth ratio among the parental as well as segregation populations (**Table 3**). As segregating generation possesses most of the variations, the variations were observed for grain color, grain shape and grain size in different F_2 populations (**Table 2 and Table 3**). The results are due to gene recombination and interaction in the segregating generations, and the environment. According to Singh *et al.* (1974) genes cannot express unless the character has the proper environment for expression.

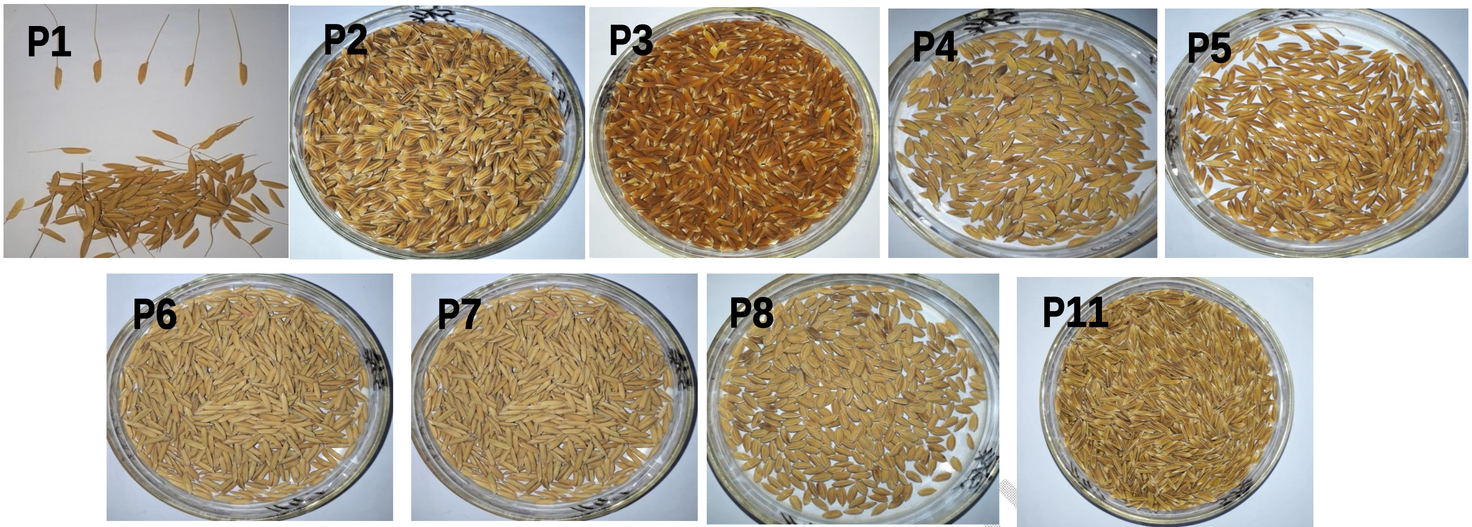

Figure 1. Grain color and shape variability observed in parental generation of Aus rice [P1 Dhalasaitta); P2 (Laksmilota); P3 (Kataktara); P4 (N-ABSS); P5 (BRRIdhan 43); P6 (BRRIdhan 55); P7 (BR 7); P8 (Japonica); P11 (Parija)].

Table 1. Mean performance of 10 parental genotypes and 15 F_2 generations for panicle length, filled grain and empty grain in Aus rice

Genotype	PLT					FGP					EGP				
	Min	Max	X	SD	CV	Min	Max	X	SD	CV	Min	Max	X	SD	CV
P1 X P4	21.10	29.00	22.80	5.60	24.57	21.20	192.66	86.08	44.11	51.24	16.33	34.66	23.41	5.07	21.69
P2 X P1	19.00	25.10	21.42	1.66	7.76	16.60	89.60	62.52	14.12	22.58	12.66	39.33	20.38	7.41	36.39
P2 X P5	18.33	26.50	21.71	1.93	8.90	18.80	95.50	56.89	16.13	28.35	5.66	39.66	19.68	6.83	34.70
P2 X P6	18.33	32.00	23.56	2.51	10.67	18.80	133.60	77.80	26.83	34.48	10.00	72.00	24.80	11.23	45.26
P3 X P4	19.30	33.83	25.64	2.65	10.36	13.60	193.00	106.93	34.06	31.86	9.00	2732	46.84	231.65	494.53
P3 X P6	15.33	31.80	25.02	3.07	12.28	14.00	172.00	102.39	32.61	31.84	13.00	83.00	26.13	12.93	49.50
P3 X P7	16.20	32.60	25.48	2.66	10.46	11.20	207.30	94.86	41.45	43.69	12.66	183.33	45.25	29.78	65.82
P4 X P6	22.00	29.00	25.47	1.76	6.94	17.20	201.66	110.80	32.95	29.74	14.00	52.33	26.29	7.26	27.64
P6 X P7	22.50	26.60	24.97	1.77	7.10	12.80	79.00	60.06	13.95	23.23	18.00	33.66	25.66	6.51	25.37
P6 X P3	18.16	282.0	27.46	22.52	82.12	12.40	179.30	98.24	32.24	32.81	5.66	104.66	34.70	17.68	50.96
P7 X P3	17.66	34.80	26.70	3.744	14.02	10.20	182.60	102.58	98.49	6.01	5.66	145.33	38.73	26.75	69.06
P7 X P6	18.00	30.60	25.24	2.09	8.28	17.20	237.60	116.57	39.12	33.59	5.33	64.33	21.74	7.99	36.74
P8 X P3	22.33	27.00	24.31	1.94	7.98	21.20	139.00	101.50	37.44	36.88	17.33	30.66	22.93	5.46	23.82
P6 X P4	19.83	26.80	24.30	1.49	6.16	19.60	142.30	102.50	19.96	19.43	14.00	267.33	6.16	54.85	151.63
P7 X P11	19.10	26.50	23.93	1.84	7.70	17.00	128.33	99.87	23.88	23.91	15.66	127.33	28.77	25.07	87.26
P1 Dhalasaitta)	10.15	25.00	22.04	3.25	14.79	25.40	107.00	79.98	15.32	19.15	23.00	27.00	24.38	0.95	3.91
P2 (Laksmilota)	12.25	24.50	19.38	2.74	14.18	21.60	80.30	46.10	20.28	43.99	13.33	28.50	18.82	4.47	23.76
P3 (Kataktara)	24.30	27.10	25.45	0.64	2.53	16.40	179.60	143.38	15.24	10.63	11.33	41.66	24.68	9.09	36.82
P4 (N-ABSS)	22.50	25.50	24.38	1.00	4.13	23.80	163.60	85.75	37.26	43.45	15.33	48.33	22.74	10.74	47.25
P5 (BRRIdhan 43)	22.83	30.10	24.47	1.42	5.83	19.20	135.60	109.27	16.54	15.13	13.33	31.33	20.03	4.00	19.98
P6 (BRRIdhan 55)	24.00	26.70	25.07	0.83	3.32	16.60	128.60	111.42	10.93	9.81	16.66	53.00	28.95	8.31	28.08
P7 (BR 7)	24.00	29.70	27.30	1.90	6.98	19.80	142.60	118.99	17.74	14.90	17.66	114.00	35.68	22.99	64.42
P8 (Japonica)	18.00	20.50	18.93	0.55	2.94	20.40	101.60	58.58	13.60	23.23	12.66	64.00	23.45	13.90	59.29
P10 (Nipponbare)	18.00	20.10	18.88	0.56	3.01	16.60	68.00	53.56	9.92	18.53	12.00	29.33	16.62	5.24	31.58
P11 (Parija)	19.00	21.60	20.08	0.69	3.43	15.40	104.60	69.36	11.98	17.27	13.33	27.00	19.72	3.51	17.79

PLT- Panicle length (cm), FGP- Filled grain (no.), EGP- Empty grain (no.)
Min= Minimum, Max= Maximum, X=Mean, SD= Standard deviation, CV (%)= Coefficient of variation.

Table 2. Mean performance of 10 parental genotypes and 15 F_2 generations for grain length, grain breadth and 1000-seed weight in Aus rice

Genotype	GLT					GBD					TSW				
	Min	Max	X	SD	CV	Min	Max	X	SD	CV	Min	Max	X	SD	CV
P1 x P4	7.79	11.61	8.45	1.14	13.48	2.23	3.73	2.84	0.49	17.43	21.2	31.4	26.04	2.91	11.20
P2 x P1	7.33	8.46	7.88	0.33	3.97	2.91	3.98	3.47	0.30	8.83	16.6	32.6	27.30	3.50	12.82
P2 x P5	7.2	8.04	7.66	0.26	2.94	3.07	3.99	3.68	0.20	5.65	18.8	46.4	32.77	6.95	11.21
P2 x P6	7.52	10.12	9.04	0.61	6.78	1.74	3.54	2.84	0.41	14.59	18.8	32	28.22	3.66	12.99
P3 x P4	7.25	8.67	9.04	0.61	6.74	1.71	3.41	2.69	0.31	11.82	13.6	27.2	24.34	5.09	20.92
P3 x P6	8.39	11.01	9.40	0.44	4.88	1.86	2.5	2.18	0.12	5.63	14	25.2	19.40	1.82	9.40
P3 x P7	6.8	10.24	8.58	0.63	7.37	1.72	27	2.80	3.39	121.14	11.2	24.4	19.91	3.61	18.13
P4 x P6	7.76	9.79	8.87	058	6.56	1.72	2.87	2.39	0.20	8.60	17.2	37	23.16	3.70	16.00
P6 x P7	8.85	9.89	9.46	0.45	4.85	1.89	2.87	2.44	0.28	11.45	12.8	30	19.93	3.66	18.39
P6 x P3	7.69	11.11	9.27	1.08	11.67	1.61	2.75	2.34	0.25	11.08	12.4	32.6	23.12	4.12	17.85
P7 x P3	7.47	821	9.36	0.67	7.15	1.25	2.68	2.33	0.23	10.14	10.2	28.6	20.64	3.15	15.30
P7 x P6	7.53	10.76	9.37	0.56	6.02	1.92	2.68	2.29	0.17	7.49	17.2	31.8	21.77	2.20	10.10
P8 x P3	7.41	8.42	7.86	0.51	6.52	1.83	2.71	2.17	0.18	8.30	21.2	29	24.46	2.88	11.80
P6 x P4	7.79	10.24	8.70	0.55	6.42	1.95	2.61	2.47	0.19	7.78	19.6	30.4	24.05	2.22	9.24
P7 x P11	7.83	9.25	8.40	0.42	5.00	1.72	2.96	2.36	0.30	13.00	17	25.6	19.48	2.05	10.56
P1 Dhalasaitta)	7.98	8.65	8.39	0.24	2.88	1.92	3.24	2.53	0.45	17.81	25.4	33.8	28.89	2.36	8.17
P2 (Laksmilota)	6.93	7.69	7.38	0.24	3.33	3.01	3.75	3.53	0.26	7.50	21.6	34.2	29.32	3.48	11.88
P3 (Kataktara)	8.08	8.83	8.38	0.23	2.78	2.36	3.73	3.00	0.57	19.11	16.4	21.8	19.21	1.16	6.03
P4 (N-ABSS)	7.99	10.65	8.72	0.79	9.12	2.19	2.51	2.30	0.10	4.45	23.8	28.9	26.39	1.31	4.96
P5 (BRRIdhan 43)	8.39	9.96	8.91	0.57	6.44	2.23	2.95	2.40	0.18	7.51	19.2	23.4	21.51	0.95	4.42
P6 (BRRIdhan 55)	9.37	10.68	9.95	0.48	4.87	2.05	2.36	2.23	0.09	4.25	16.6	32.4	23.15	3.29	14.22
P7 (BR 7)	8.79	10.05	9.36	0.35	3.77	2.12	3.1	2.62	0.36	13.82	19.8	25.2	21.56	1.48	6.88
P8 (Japonica)	6.64	7.77	7.23	0.34	4.71	2.17	3.45	2.65	0.53	20.07	20.4	24.4	22.55	1.05	4.65
P10 (Nipponbare)	7.95	8.9	8.50	0.28	3.36	2.42	3.19	2.78	0.32	11.78	16.6	33.4	28.43	4.97	17.51
P11 (Parija)	7.41	7.87	7.66	0.16	2.13	2.8	3.25	3.05	0.18	6.18	15.4	22	18.72	2.22	11.86

GLT= Grain length (mm), GBD= Grain breadth (mm), TSW= 1000-Seeds weight (g)
Min= Minimum, Max= Maximum, X=Mean, SD= Standard deviation, CV (%)= Coefficient of variation.

Table 3. Appearance quality parameters for instance grain color, grain shape, 1000-grain weight, grain length (L), grain breadth (B) and L/B ratio of 15 F_2 populations and 10 parental genotypes

Genotypes	Grain Color				Grain Shape			TSW	Grain Length	Grain Breadth	Grain Size (L/B ratio)			
	Golden	Brown	Red	Black	Spindle	Half Spindle	Semi round				L/B Ratio	Slender	Medium	Bold/ Round
P1 x P4	√						√	26.04	8.45	2.84	2.98		√	
P2 x P1	√						√	27.3	7.88	3.47	2.27		√	
P2 x P5	√						√	32.77	7.66	3.68	2.08		√	
P2 x P6	√					√	√	28.22	9.04	2.84	3.18	√		
P3 x P4	√	√	√	√	√	√	√	24.34	9.04	2.69	3.36	√		
P3 x P6	√				√	√		19.4	9.4	2.18	4.31	√		
P3 x P7	√	√	√		√	√	√	19.91	8.58	2.8	3.06	√		
P4 x P6	√					√		23.16	8.87	2.39	3.71	√		
P6 x P7	√					√		19.93	9.46	2.44	3.88	√		
P6 x P3	√	√	√	√	√	√	√	23.12	9.27	2.34	3.96	√		
P7 x P3	√	√	√		√	√		20.64	9.36	2.33	4.02	√		
P7 x P6	√				√	√		21.77	9.37	2.29	4.09	√		
P8 x P3	√						√	24.46	7.86	2.17	3.62	√		
P6 x P4	√					√	√	24.05	8.7	2.47	3.52	√		
P7 x P11	√					√	√	19.48	8.4	2.36	3.56	√		
P1 Dhalasaitta)	√						√	28.89	8.39	2.53	3.32	√		
P2 (Laksmilota)	√						√	29.32	7.38	3.53	2.09		√	
P3 (Kataktara)			√		√			19.21	8.38	3	2.79		√	
P4 (N-ABSS)	√						√	26.39	8.72	2.3	3.79	√		
P5 (BRRIdhan 43)	√					√		21.51	8.91	2.4	3.71	√		
P6 (BRRIdhan 55)	√				√			23.15	9.95	2.23	4.46	√		
P7 (BR 7)	√				√			21.56	9.36	2.62	3.57	√		
P8 (Japonica)	√						√	22.55	7.23	2.65	2.73		√	
P10 (Nipponbare)	√						√	28.43	8.5	2.78	3.06	√		
P11 (Parija)	√					√		18.72	7.66	3.05	2.51		√	

TSW- 1000-Seed weight (g), L/B Ratio – Length-breadth ratio

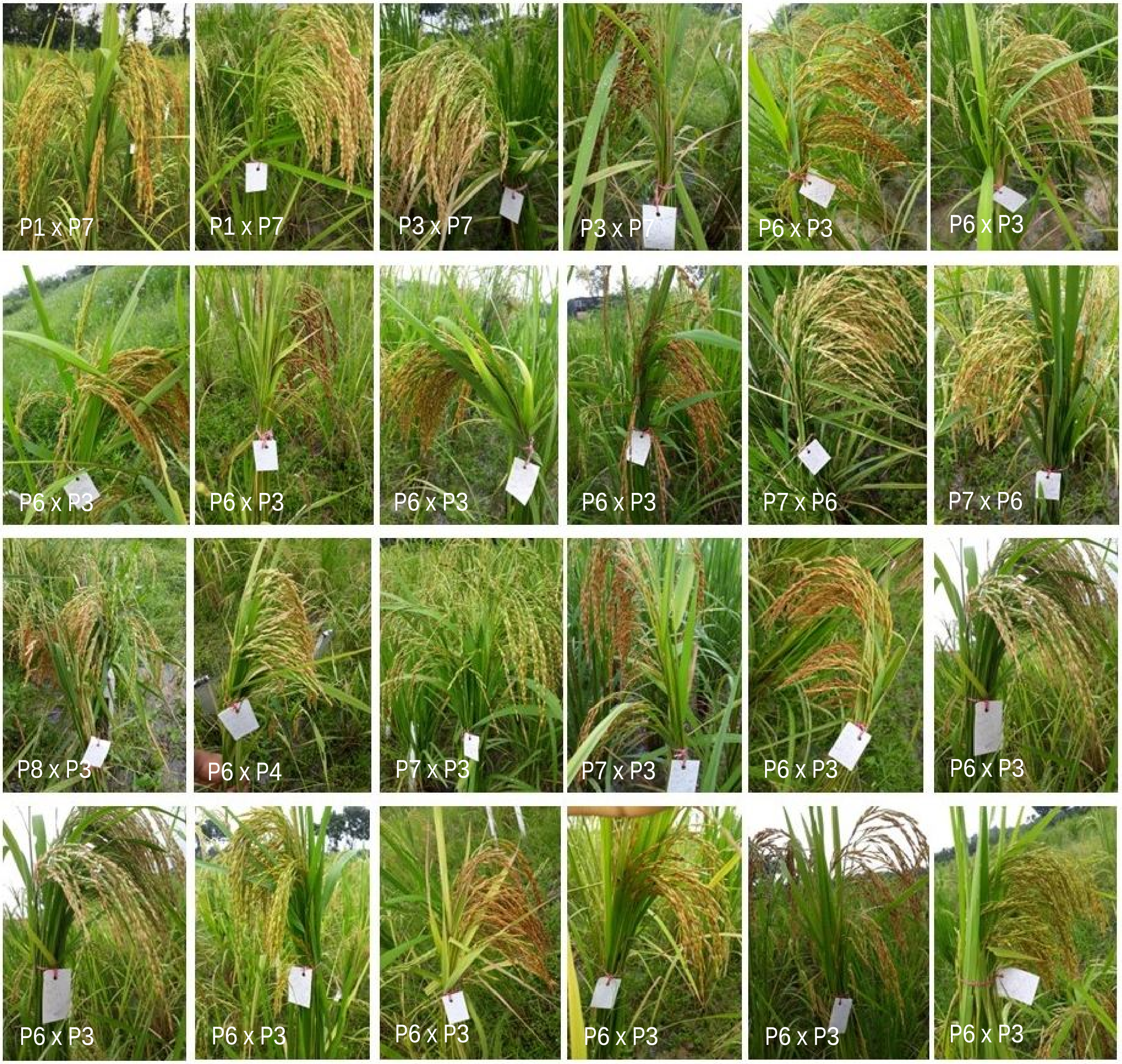

Figure 2(A). Panicle length, grain number in panicle, grain color and shape variability observed in F_2 generation of Aus rice.

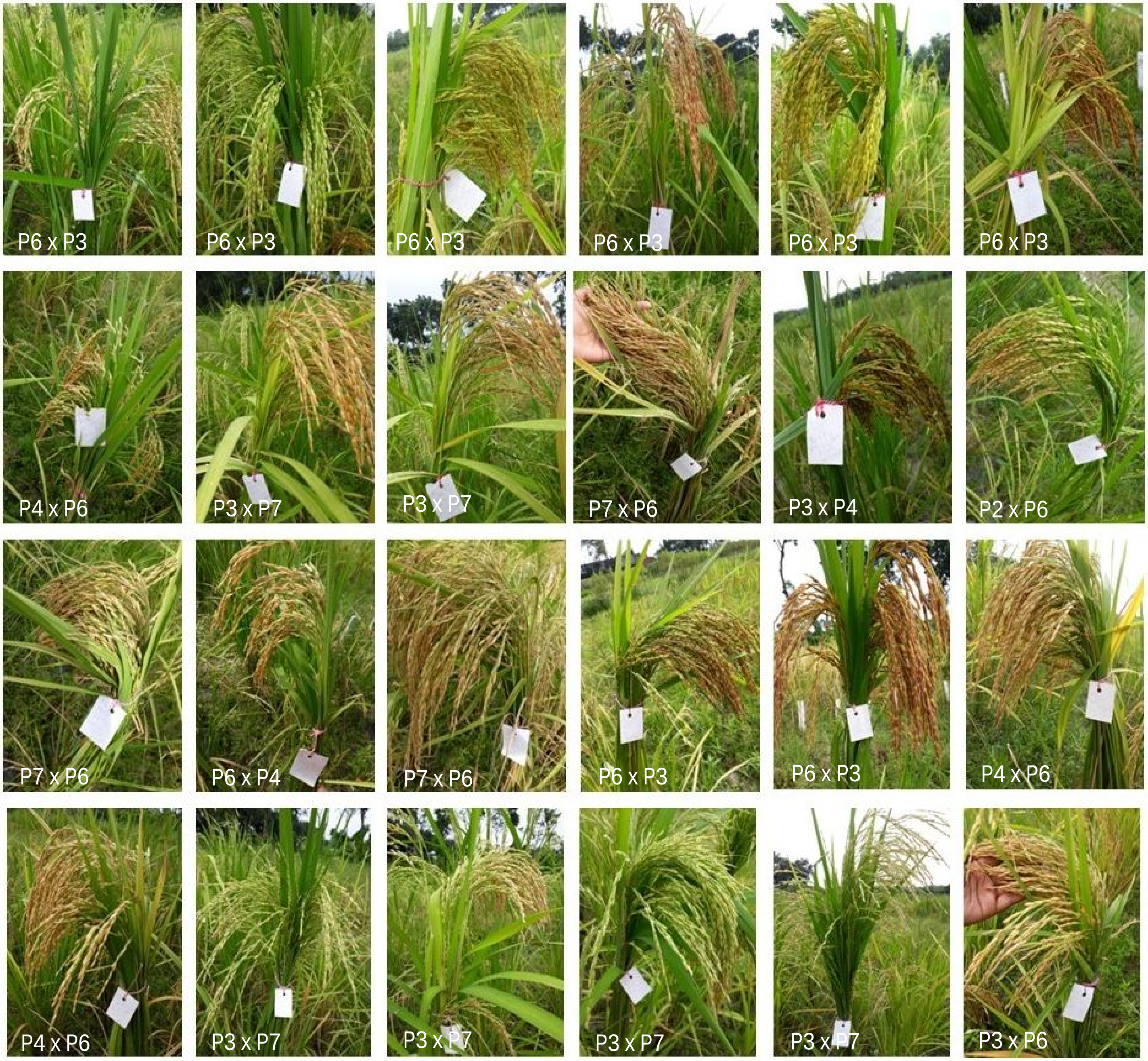

Figure 2(B). Panicle length, grain number in panicle, grain color and shape variability observed in F_2 generation of Aus rice.

The maximum mean value for thousand seed weight was found from the genotypes P2 (29.32; max 34.2), P1 (28.89; max 33.8), and F_2 generations of P2 x P5 (32.77; max 46.4), P2 x P1

(27.30; max 32.60), P1 x P4 (26.04; max 31.40). These three crosses were considered as high yielders in terms of grain weight.

Longer grain length with smaller grain breadth is considered as desirable characteristic for the development of fine grain rice. The highest mean values for grain length were found from the genotypes P6 (9.95 mm; grain breadth 2.23 mm), P7 (9.36 mm; grain breadth 2.62 mm), and F_2 generations of P6 x P7 (9.46 mm; grain breadth 2.44 mm), P3 x P6 (9.40 mm; grain breadth 2.18 mm), P7 x P6 (9.37 mm; grain breadth 2.29 mm), P7 x P3 (9.36 mm; grain breadth 2.33 mm). The F_2 progenies of the cross P1 x P4 (7.79 to 11.61) and P6 x P3 (7.69 to 11.11) showed extremes performance for grain length, indicating transgressive segregation for this trait in this populations (**Table 2**) and several genes are responsible for the genetic control of this trait.

Extensive transgressive segregation was noticed in the segregating generations from the crosses P3 x P4, P3 x P7, P6 x P3 and P7 x P3 for grain color and grain shape. Anilkumar (2008) observed similar results in segregating generations for grain parameters. Almost all parents had golden color grain except P3 which had red colored grain. In case of crosses, P3 x P4, P3 x P7, P6 x P3 and P7 x P3 showed four grain colors and were golden, brown, black and red (**Figure 1**). All other crosses showed golden grain color. For grain shape, parents with specific shape were changed to intermediate type in cases of crosses. The genotypes P3 and P4 showed spindle and round shaped grain, respectively but the segregating generations of the hybrid P3 x P4 showed spindle, half spindle and round shaped grain. The parents P3 and P6 had spindled shaped grain, but segregating generations of the crosses between these parents produced spindle, half spindle and round shaped grain. Savitha and Kumari (2016) observed spindle and half spindle grains in segregating generations for grain parameters.

Length-breadth ratio is an important aspect to measure grain size. Usually grain size and shape of rice grain measured by visual observation but more accurate measurements are required in case of critical assessment of grain quality of the genotypes (Sultana et al., 2022). Based on grain L/B ratio, Cruz and Khush (2000) classified rice grain into three sizes, namely, slender (above 3.00 mm), medium (2.1 – 3.00 mm) and bold or round (2.00 or below 2.00 mm) (Rice descriptor, IRRI). Among 15 F_2 families, nine had grain length-breadth ratio >3.00 and designated as slender grain, and three (P3 x P6: 4.13; P7 x P6: 4.09 and P6 x P3: 4.00) had grain length-breadth ratio >4.00 and can be designated as extra slender grain. The rest of the genotypes viz., P1 x P4, P2 x P1, P2 x P5 along with P2, P3, P8 and P11 had medium sized grain. Though the parents P8 and P11 have bold grain, but they produced slender grain when involved in the cross combinations of P8 x P3 and P7 x P11 (**Table 3**). None of the parents and segregating generation showed bold or round grain.

Conclusion

There were significant differences for panicle length, number of grains per panicle, grain color and grain shape among the F2 segregation populations of different cross combinations of parental genotypes. In case of crosses, P3 x P4, P3 x P7, P6 x P3 and P7 x P3 showed four grain colors and were golden, brown, black and red. Extensive transgressive segregation was noticed in the segregating generations of from the crosses P3 x P4, P3 x P7, P6 x P3 and P7 x P3 for grain color and grain shape. For grain shape, the genotypes P3 and P4 showed spindle and round shaped grain, respectively but the segregating generations of the hybrid P3 x P4 showed spindle, half spindle and round shaped grain. For L/B ratio, segregating populations of P1 x P4, P2 x P1, and P2 x P5 had medium sized grain and rest of the genotypes showed slender grain.

Acknowledgements

The authors would like to acknowledge their gratitude towards Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur 1706, Bangladesh for the support towards the completion of the research.

Conflict of Interest

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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