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Research Article

Yield Potentiality and Grain Physio-Chemical Properties of Some Advanced Lines and High Yielding Varieties of Rice in Bangladesh

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Abstract

Background and Objective: Rice is the main food in many countries globally, which is an excellent source of carbohydrates and energy. Higher yield, milling, cooking and eating quality are crucial factors for customers to fulfil their nutrition. The study was conducted to reveal the yield potentiality, cooking and eating properties of three advanced lines and two high yielding rice varieties. **Materials and Methods:** Three advanced lines (AL-29, AL-36 and AL-18) and two check varieties (BRRI dhan 39 and BRRI dhan 49) of rice were used as planting materials to determine growth and yield performance. **Results:** The findings indicated that advanced line AL-29 and AL-36 could produce higher yields, while AL-18 and AL-29 were better for cooking and eating quality. **Conclusion:** Therefore, advanced lines AL-29 could play a significant role in increasing yield and quality rice for balanced nutrition. Moreover, comprehensive chemical and physical properties of rice and molecular analysis of signalling pathways can be introduced in future research to get molecular evidence to improve those varieties.

Key words: Alkali spreading value, cooking quality, eating quality, gelatinization temperature, grain yield, milling quality

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Food security is the primary goal for all nations to eliminate poverty and soon it will be a challenging issue. Although the global population increases with time, it is crucial to increase crop production to satisfy people's demands[1]. It is projected that to feed the whole population in 2050, crop production will be needed to increase by 100-110%[2]. However, the developed crop varieties in the world are not enough to fulfil the food demand for the future populations. Therefore, developing new High-Yielding Varieties (HYV) with high quality is most important to save our future generation.

Rice (*Oryza sativa* L.) consider one of the highly consumed crops worldwide and more than 50 percent of the global population consumes rice as a staple food and projects that in 2050 its demand will increase by 28%[3]. Moreover, it is one of Asia's primary dietary energy sources, followed by North and South America and Africa[4]. The total amount of rice produced globally was around 782 M t from 162 M ha[5], in 2011 Bangladesh contributed 33.542 M ton[6]. Nearly 75% of the total crop field grows rice, so it plays a crucial role in the livelihood of many people in Bangladesh. Even though the population growth is higher (about 164 M) than in the past, modern HYV (hybrid or advanced line) struggles to fulfil the people's demands. The adoption of hybrid rice and the latest technology can increase the total rice production in Bangladesh. So far Bangladesh Rice Research Institute (BRRI) has developed seven hybrid varieties of rice[7]. Furthermore, BRRI has developed many HYV of rice. BRRI dhan 28 and BRRI dhan 29 are internationally competitive mega varieties. However, more high-yielding hybrid rice varieties will require meeting massive population demands in the upcoming days.

Crop yield is crucial in agriculture as is a yield increase through new technology for world food security[8]. The yield of rice as influenced by genotype and environment. To increase the total production, high-yielding rice varieties are need to be developed and yield variation due to environmental influence can be controlled by developing seasonal crop varieties to maximize production. Currently, BRRI has a total of 102 rice varieties, which comprises hybrid rice (7), zinc enriched (5), drought-tolerant (7), submergence tolerant (3), antioxidant variety (1), low GI varieties (3) and high yielding varieties[7]. However, developing a more hybrid and advanced rice line is crucial to fulfil people's demands and establish a complete food-secure nation.

The grain quality of rice is a compound factor that contains many components, for instance, grain appearance, milling appearance, nutrition, cooking and eating quality. Consumers highly focus on pleasing appearance and higher eating quality of rice, which led to the primary goal of rice quality improvement[9]. Previous studies also indicate that rice-eating quality is directly related to three physio-chemical properties, namely, amylose content[10], gel consistency[11] and gelatinization temperature[12]. Although rice production is increased due to hybrid rice variety, it is also necessary to improve and raise consumers' acceptability toward the grain quality of hybrid rice. A cultivar with different grain quality can be used for medicinal, ceremonial and other notable production purposes. However, to compete with the current population growth in Bangladesh, it's crucial to increase rice production and improve grain quality. Moreover, both higher yield production and better grain quality can allow Bangladeshi rice to be widespread worldwide. Therefore, the study was conducted to observe the yield performance and grain physio-chemical properties of some advanced lines and HYV of rice in Bangladesh.

MATERIALS AND METHODS

Study area: The experiment was conducted in the Sher-e-Bangla Agricultural University Research farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from June to December, 2014. The experimental area was situated at 23°77'N latitude and 90°23'E longitude at an altitude of 8.6 m above sea level.

Plant materials: Three advanced lines (AL-29, AL-36 and AL-18) and two check varieties (BRRI dhan 39 and BRRI dhan 49) of rice were used as planting materials and collected from BRRI. Seeds were immersed in water overnight, then transferred from the water and allowed for sprouting. After 48 hrs sprouting seedlings sown in nursery seedbeds. The seedlings of thirty days old were transplanted in a 3 m×2 m unit plot with the spacing of 25×20 cm between rows and plants and the plot-to-plot distance was 1 m. Proper fertilizer doses, intercultural crop management and plant protection measures are conducted successfully to better yield performance. The experiment was arranged following a Randomized Complete Block Design (RCBD) with three biological replications and five treatments.

Determination of growth and yield components: Growth and yield performance of rice plants was determined by considering the evaluation of some components such as plant height (cm), number of tillers plant^{-1}, number of effective tillers plant^{-1}, days to 50% flowering, panicle length (cm), days to maturity, number of filled grains plant^{-1}, the number of empty grains plant^{-1}, 1000 grains weight (g), grain yield (g plant^{-1}), grain yield (kg plot^{-1}) and grain yield (t ha^{-1}).

Estimation of hulling, milling and head rice recovery percentages: Well-dried paddy or rough rice (200 g) was hulled in a mini Satake rice machine and the weight of brown rice was recorded. Hulling percentage was estimated according to Thongbam *et al.*[13] through the following Eq.:

$$\text{Hulling (\%)} = \frac{\text{Weight of brown rice}}{\text{Weight of rough rice}} \times 100$$

Milling percentage was estimated by introducing brown rice into the Satake rice whitening and caking machine for 5 minutes to get uniform and polished grains and the weight of polished grains or milled rice was recorded. Milling percentage was estimated according to Thongbam *et al.*[13] by using the following formula:

$$\text{Milling (\%)} = \frac{\text{Weight of milled rice}}{\text{Weight of rough rice}} \times 100$$

Milled rice was sieved and separated whole kernels from the broken ones to estimate head rice recovery (HRR) percentage. The percentage of HRR was calculated according to Thongbam *et al.*[13] by using the following formula:

$$\text{HRR (\%)} = \frac{\text{Weight of whole kernels milled rice}}{\text{Weight of rough rice}} \times 100$$

Determination of length and breadth ratio: Length and breadth of rough rice, brown rice, milled rice and cooked rice was observed to determine L/B ratio by the following formula:

$$\text{L/B ratio} = \frac{\text{Grain length}}{\text{Grain breadth}} \times 100$$

Estimation of water absorption percentages: Water absorption percentage (WAP) was estimated according to Bello *et al.*[14] by using milled rice kernel (1 g) in a long test tube and pre-soaked for 5 min. Afterwards, test tubes were placed in a water bath maintained at 100°C for 6-7 min. Then, test tubes were allowed to cool at room temperature for 10 min and excess water was removed using blotting papers. The weight of rice was recorded before (W_1) and after (W_2) cooking. Therefore, WAP was calculated as follows:

$$\text{WAP} = \frac{W_2 - W_1}{W_1} \times 100$$

Determination of volume expansion percentage: The volume expansion percentage (VEP) was estimated according to Bello *et al.*[14] by using the water method through a finely graduated 5 ml narrow cylinder. The volume of rice was recorded before (V_1) and after (V_2) cooking and VEP was estimated by using the following Eq.:

$$\text{VEP} = \frac{V_2 - V_1}{V_1} \times 100$$

Observation of alkali spreading value and gelatinization temperature: Alkali spreading value (ASV) and gelatinization temperature (GT) were observed following the method of Majumder *et al.*[12]. A sample of eight whole milled rice kernels from each entry is placed in a 5 cm small Petri dish containing 10 mL of 1.7% potassium hydroxide (KOH) solution. The Petri dishes were kept in the incubator maintained at 30±1°C for 16 hrs. After 16 hrs of incubation, the petri dish is gently taken out of the incubator. The ASV of six grains of each entry was recorded separately and the mean values were calculated on a 7-point numerical scale. Gelatinization temperature was classified according to the 7-point numerical scale of ASV. The ranges of ASV 1-3, 4-5 and 6-7 were represented the high, intermediate and low GT.

Statistical analysis: The genotypic and phenotypic correlation coefficient and path co-efficient were measured according to Shompa *et al.*[15]. All data were analyzed by one-way Analysis of Variance (ANOVA) with statistical software statistix10. Fisher's least significant difference (LSD) test was employed for mean comparisons, where $p \leq 0.05$ was considered significant.

RESULTS

Growth and yield performance of advanced lines and high yielding varieties of rice: The results indicated the highest plant height was for BRRI dhan 49 (106.5 cm), which was statistically similar with BRRI dhan 39 and AL-29, while the shortest one was AL-36 (95.70 cm) in Fig. 1a. The maximum number of tillers plant^{-1} was observed in AL-36 (22.33), which is statistically not different from BRRI dhan 49 and AL-29 in Fig. 1b. The highest number of effective tillers was also observed in AL-36 (2.87), where AL-29 produced minimum effective tillers (1.2) in Fig. 1c. For 50% flowering, the highest

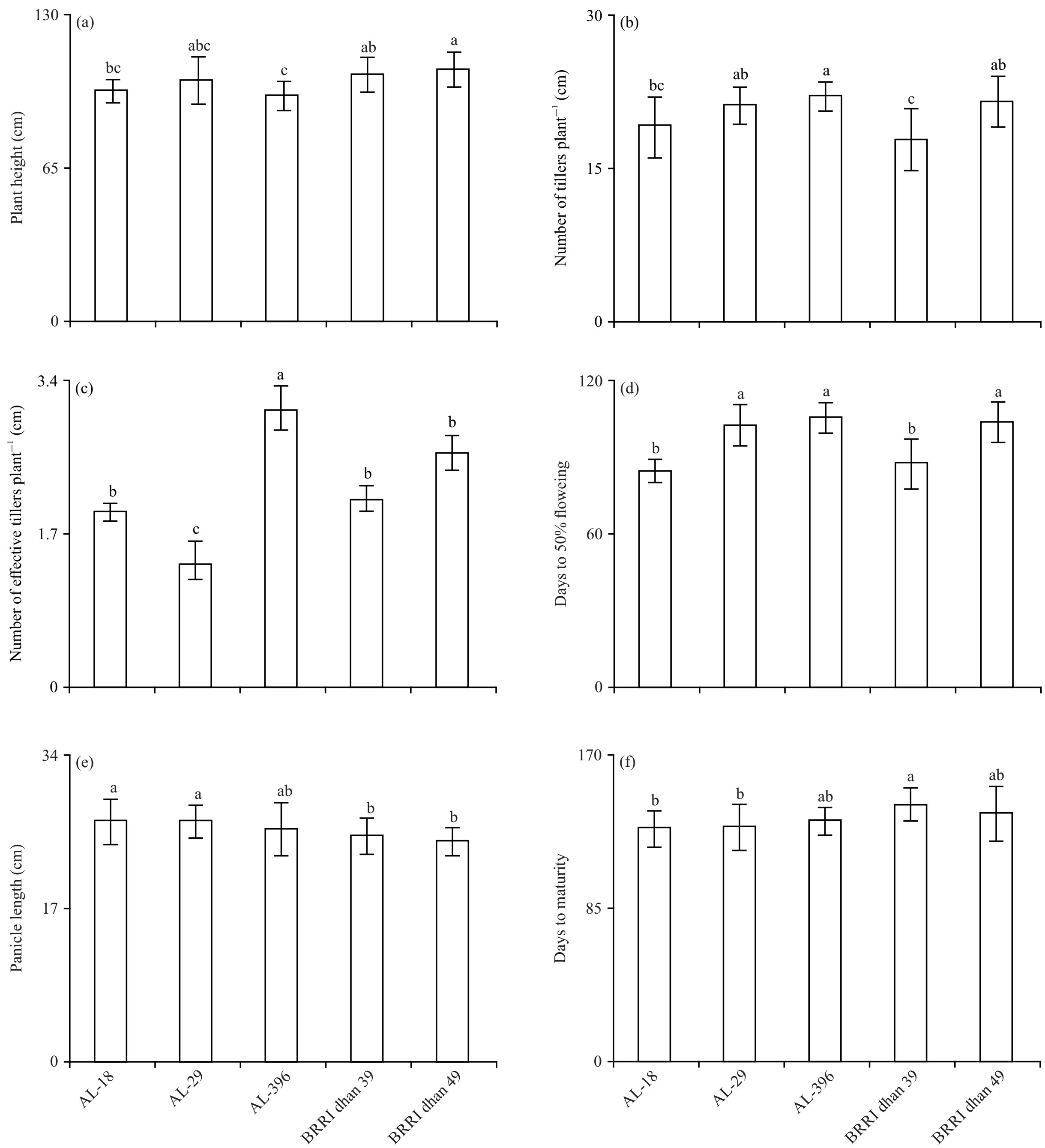

Fig. 1(a-f): Performance on growth-related attributes in advanced lines and high yielding varieties of rice, (a) Plant height, (b) Number of tillers plant^{-1}, (c) Number of effective tillers plant^{-1}, (d) Days to 50% flowering, (e) Panicle length and (f) Days to maturity

number of days was also observed in the AL-36 line (106 days), whereas AL-18 took minimum days (85 days) in Fig. 1d. In AL-29, panicle length was the highest (26.68 cm) which was statistically similar to AL-18 (26.62 cm), while the shortest panicle length was recorded in BRRI dhan 49 (24.35 cm) in Fig. 1e. For maturity, BRRI than 39 was required more days (142 days) where minimum days were needed for AL-18 (128.7 days) in Fig. 1f.

The advanced line AL-29 showed the maximum filled grain (178.30), where minimum filled grain was observed in BRRI dhan-39 (147.30) in Fig. 2a. Consequently, the highest number of empty grains was found in BRRI dhan 39(22),

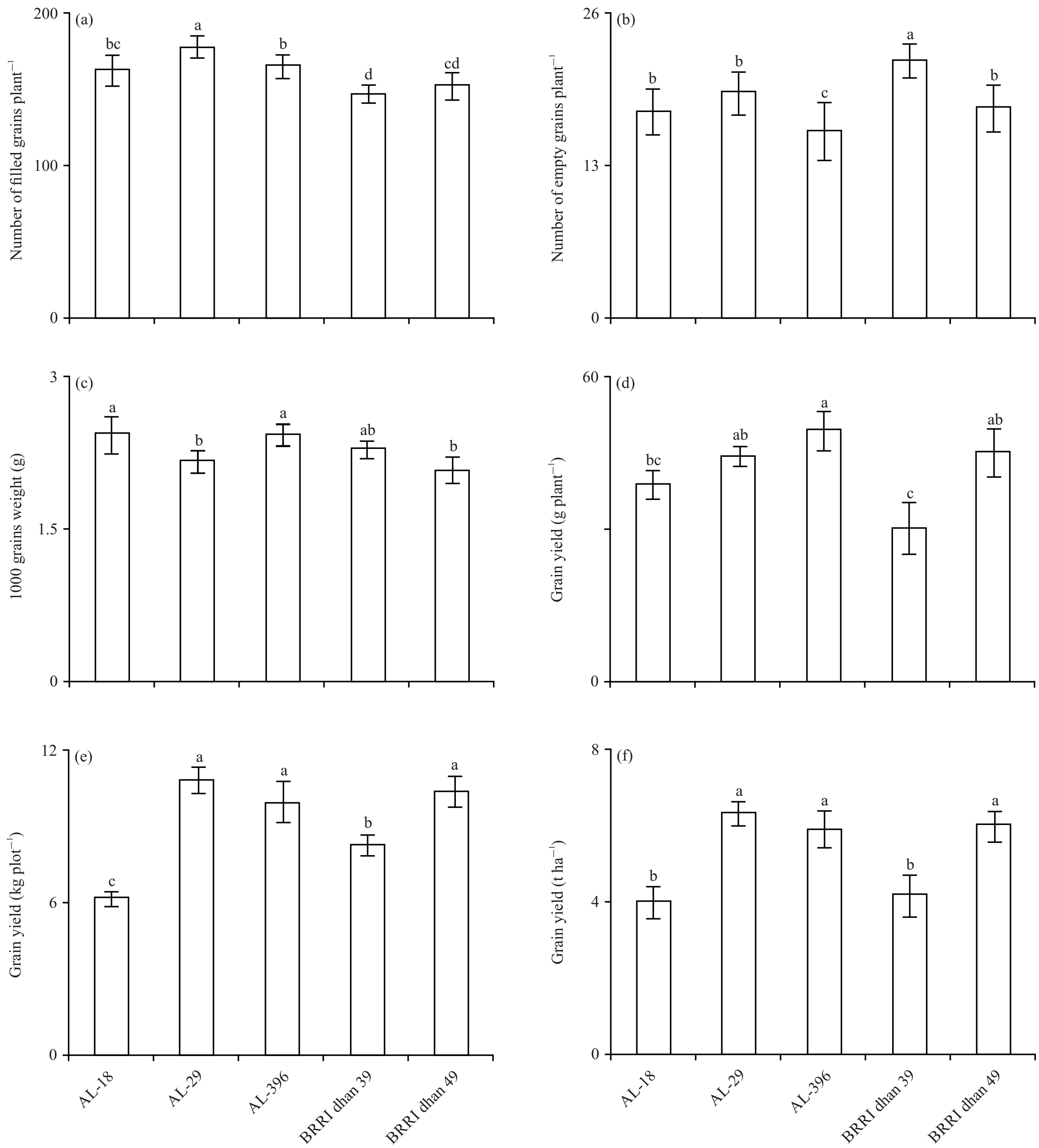

Fig. 2(a-f): Performance on yield-related attributes in advanced lines and high yielding varieties of rice, (a) Number of filled grains plant^{-1}, (b) Number of empty grains plant^{-1}, (c) 1000 grains weight, (d) Grain yield plant^{-1}, (e) Grain yield plot^{-1} and (f) Grain yield ha^{-1}

whereas the lowest number of empty grains was observed in AL-36 (15.93) (Fig. 2b). The highest grain weight of 1000 seeds and grain yield per plant was found in AL-36 and values were 2.43 and 49.19 g, respectively in Fig. 2c and d. However, the highest grain yield per plot (10.75 kg) and grain yield per hectare (6.32 ton) were observed in AL-29, which is statistically similar with AL-36 and BRRI dhan 49 in Fig. 2e and f.

Correlation of growth and yield components: Phenotypic correlation data showed that the grain yield has a positive relationship with the plant height (0.10), days to 50% flowering (0.97), number of tillers per plant (0.89), number of filled grains per plant (0.52) and 1000 grain weight (0.94), whereas the negative relationship was illustrated with the number of effective tillers per plant (-0.02), panicle length

Table 1: Phenotypic and genotypic correlation among different growth and yield-related attributes of rice

Characters	NTP	NETP	DF	PL	DM	NFGP	NEGP	GW	GY
PH									
r_p	-0.23	-0.35	0.02	-0.67	0.63	-0.47	0.66	-0.88	0.10
r_g	-0.42	-0.29	-0.12	-0.89	0.46	-0.53	0.67	-0.94	0.12
NTP									
r_p		0.31	0.93	0.05	-0.34	0.50	-0.75	-0.18	0.89
r_g		0.37	0.85	-0.09	-0.54	0.48	-0.81	-0.26	0.94
NETP									
r_p			0.22	-0.44	0.27	-0.44	-0.54	0.43	-0.02
r_g			0.29	-0.38	0.37	-0.45	-0.53	0.50	-0.04
DF									
r_p				-0.17	-0.06	0.39	-0.48	-0.40	0.97
r_g				-0.32	-0.23	0.36	-0.52	-0.52	0.97
PL									
r_p					-0.85	0.81	-0.23	0.48	-0.06
r_g					-0.97	0.79	-0.28	0.39	-0.03
DM									
r_p						-0.83	0.60	-0.31	-0.16
r_g						-0.91	0.60	-0.44	-0.11
NFGP									
r_p							-0.41	0.06	0.52
r_g							-0.44	0.03	0.55
NEGP									
r_p								-0.36	-0.39
r_g								-0.35	-0.39
GW									
r_p									0.94
r_g									0.95

PH: Plant height, NTP: Number of tillers plant^{-1}, NETP: Number of effective tillers plant^{-1}, DF: Days to 50% flowering, PL: Panicle length, DM: Days to maturity, NFGP: Number of filled grain plant^{-1}, NEGP: Number of empty grain plant^{-1}, GW: 1000 grain wt., and GY: Grain yield (t ha^{-1})

(-0.06), days to maturity (-0.16) and number of empty grains per plant (-0.39) in Table 1.

Qualitative properties of fresh rice grain: Before cooking, the maximum hulling percent was recorded in AL-36 (81%), whereas the minimum portion (76.67%) was recorded in AL-18. The lowest milling percent was also observed in AL-18 (69.1%). However, the maximum head rice recovery percent was found in BRRI dhan 49 (67.27%), while AL-36 showed the minimum (63.17%) in Fig. 3a.

In rough rice, length and breadth were highest in the AL-18 line, 9.66 and 1.91 mm, respectively. However, the shortest and smallest unpolished rice was observed in BRRI dhan 49 (8.30 and 1.69 mm). Consequently, the highest L/B ratio was recorded in the AL-18 line, whereas the minimum L/B ratio was found in AL-29 (4.88 mm) Fig. 3b.

Interestingly, the longest brown rice was recorded in BRRI dhan 39 (6.81mm), but the maximum breadth was found in line AL-18 (1.79 mm). However, the highest L/B ratio of brown rice was recorded in BRRI dhan 39 (4.08), which is not statistically different from AL-29 and AL-36 in Fig. 3c.

The longer milled rice was recorded in AL-18, while BRRI dhan 49 showed the shortest one. The maximum thicker milled rice was also observed in AL-18 (1.67 mm). Surprisingly, the L/B ratio was highest in BRRI dhan 39 (4.60 mm), while BRRI dhan 49 showed a minimum (3.81 mm) in Fig. 3d.

Qualitative properties of cooked rice grain: After cooking, the longest and thickest rice was observed in BRRI dhan 39, which was made at 9.35 and 2.43 mm, respectively, whereas the shortest and thinnest rice was found in BRRI dhan 49. Consequently, the L/B ratio was highest in BRRI dhan-39 (4.14) and the lowest in BRRI dhan 49 (3.68) in Fig. 4a.

The full WAP was found by BRRI dhan-49 (6.93%), while BRRIdhan-39 absorbed less water (3.85%). The highest VEP was recorded in AL-29 (72.33%), while AL-18 showed a minimum (45.62%). The ASV was highest in BRRI dhan 49 (6.93), while the lowest value was indicated by BRRI dhan-39 (3.85) in Fig. 4b-d. The highest GT was observed in BRRI dhan-39 and the lowest was found in AL-36 and BRRI dhan-49, while AL-18 and AL-29 showed the intermediate GT in Table 2.

Correlation of qualitative traits of rice grain: In phenotypic correlation, the hulling percentage was positively correlated with milling percentage (0.18) but negatively correlated with HRR percentage (-0.70), while the milling rate was positively

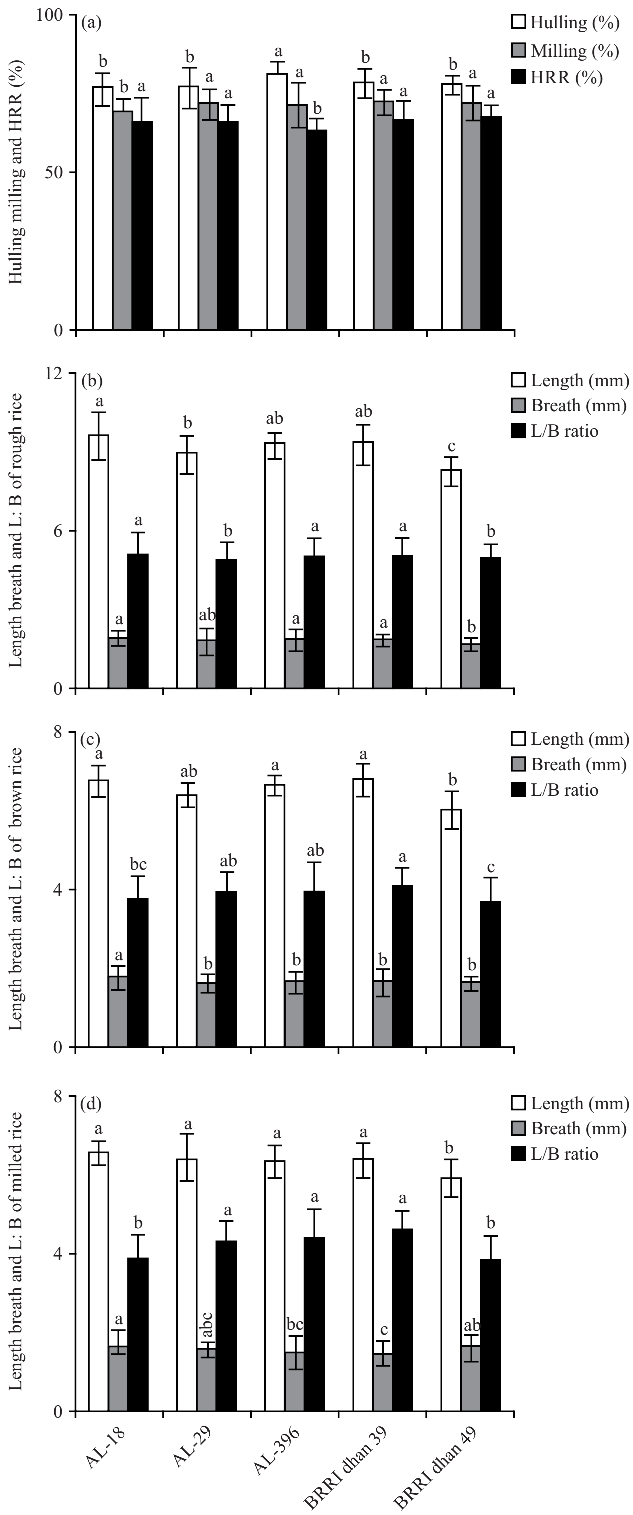

Fig. 3(a-d): Performance on the qualitative properties of fresh rice grain of advanced lines and high yielding varieties, (a) Hulling, milling and HRR percentage, (b) Length, breadth and L/B ratio of rough rice, (c) Length, breadth and L/B ratio of brown rice and (d) Length, breadth and L/B ratio of milled rice

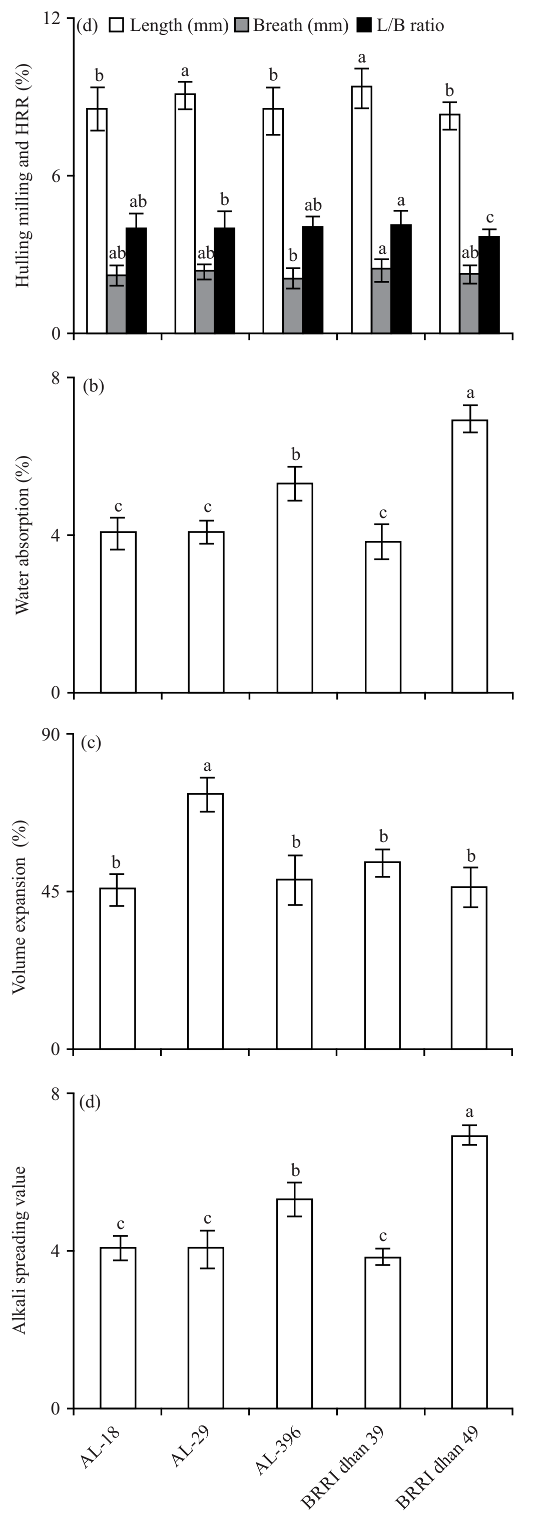

Fig. 4(a-d): Performance on the qualitative properties of cooked rice grain of advanced lines and high yielding varieties, (a) Length, breadth and L/B ratio of cooked rice, (b) Water absorption percentage, (c) Volume expansion percentage and (d) Alkali spreading value

Table 2: Gelatinization temperature advanced lines and high yielding varieties of rice

Genotypes	Gelatinization temperature
AL-18	Intermediate
AL-29	Intermediate
AL-36	Low
BRRI dhan-39	High
BRRI dhan-49	Low

Table 3: Phenotypic and genotypic correlation among qualitative traits of rice grain

Characters	MP	HRRP	RRR	RBR	RMR	RCR	WAP	VEP	ASV
HP									
r_p	0.18	-0.70	0.21	0.34	0.45	0.19	0.46	-0.31	0.32
r_g	-0.51	-0.95	-0.46	0.19	0.49	0.11	0.37	-0.41	0.32
MP									
r_p		0.45	-0.26	0.30	0.40	-0.05	-0.21	0.01	0.23
r_g		-0.32	-0.78	-0.48	0.27	-0.39	-0.61	-0.33	0.19
HRRP									
r_p			-0.34	-0.44	-0.44	-0.52	-0.42	0.02	0.21
r_p			-0.96	-0.69	-0.44	-0.66	-0.56	-0.01	0.21
RRR									
r_p				0.08	0.03	0.51	-0.55	-0.74	-0.26
r_g				-0.78	0.03	0.47	-0.82	-0.87	-0.45
RBR									
r_p					0.98	0.85	-0.17	0.42	-0.66
r_g					0.90	0.80	-0.30	0.38	-0.70
RMR									
r_p						0.76	-0.06	0.41	-0.52
r_g						0.80	-0.08	0.37	-0.52
RCR									
r_p							-0.44	0.14	-0.84
r_g							-0.50	0.14	-0.87
WAP									
r_p								0.26	0.52
r_g								0.21	0.53
VEP									
r_p									-0.44
r_g									-0.44

HP: Hulling percentage, MP: Milling percentage, HRRP: Head rice recovery percentage, RRR: L/B ratio of rough rice, RBR: L/B ratio of brown rice, RMR: L/B ratio of milled rice, RCR: L/B ratio of cooked rice, WAP: Water absorption percentage, VEP: Volume expansion percentage and ASV: Alkali spreading value

correlated with HRR percentage (0.45). The L/B ratio of rough rice was positively correlated with the L/B ratio of brown (0.08), milled (0.03) and cooked rice (0.51) but negatively correlated with WAP (-0.55), VEP (-0.74) and ASV (-0.26). A positive correlation was also observed in the L/B ratio of brown rice with the L/B ratio of milled (0.98) and cooked rice (0.85) and in the L/B ratio of milled rice with the L/B ratio of cooked rice (0.76) in Table 3.

DISCUSSION

Bangladesh is an agricultural country, where nearly 157 M people consume rice as a staple food. It plays a crucial role in nation-wise overall crop production, food processing, food security and nutrition. The goal of our study is mainly focused on the yield performance of some advanced rice lines and popular varieties in Bangladesh and analysis of their milling, cooking and eating properties. Three advanced rice lines (Al-18, Al-29, Al-36) and two check varieties (BRRI dhan 39, BRRI dhan 49) were used in this study, where plant height (cm), days to 50% flowering, number of tillers per plant, days to maturity, number of effective tillers per plant, length of panicle (cm), number of filled grain per plant, 1000 grain weight (g), grain yield per plant (g), grain yield per plot (kg) and grain yield (t ha^{-1}) those characters are included to measuring the yield performance of selected rice lines. Likewise, studies on different high yielding hybrid rice also showed the significance of those characters in yield performance[16]. To make the selection of yield, it is necessary to consider all the yield characteristics into consideration. Remarkably, AL-29 was sought to be high-yielding rice lines by considering all yield-related characters. Research on upland and irrigated rice revealed that days to 50% flowering is significantly associated with grain yield[17,18]. Alike, the number of tillers per plant and 1000 grain weight in hybrid rice were also significantly correlated with total grain yield[19,20]. Current study found the significance of those characters on rice yield. It indicates that these characters need to be prioritized to get maximum yield.

Quality is a complex trait in rice breeding. To improve such complex traits, it is important to consider the nature and strength of different quality component indices. Usually, rice quality is determined by grain appearance, cooking quality and nutritional value. The grain is crucial for getting more economic benefits for farmers and consumer acceptability. The term quality in rice is a combination of several physical-chemical characters of the grain. The physical properties of the rice grains are determined by grain colour, shape, size, weight, the hardness of the endosperm, appearances of the milled kernels, hulling and milling recovery. Moreover, the chemical components of rice grains are starch, protein, minerals and vitamins. The market quality usually depends on physical attributes, while the consumer's preference (cooking, eating and nutritive value) is depending on chemical traits. Therefore, both properties are brought into consideration. To produce white and polished rice grain, milling is a crucial process, where two parameters are predominantly considered: Head rice yield (HRY) and kernel whiteness[21]. Moreover, length, breadth, L/B ratio of rice and hulling percentage are also considered physical quality traits to analyze rice grain quality before cooking. However, WAP and VEP of rice are essential to the properties of cooked rice. Some rice lines were absorbed more water, but their expansion was low such as AL-36, while Al-18 and Al-29 lines were absorbed less water but expanded significantly. Consequently, the eating quality of rice was also determined by water absorption and rice expansion features.

Normally, rice starch has a semi-crystalline structure disrupted by cooking and transformed into a softer, edible, gel-like material. Due to cooked rice's cooking time and texture, cooled rice starch gelatinizes at a certain temperature, which plays a crucial role in determining rice-eating quality[22]. The GT and ASV have significantly influenced rice chemical properties. Generally as V and GT are inversely related to each other. Lower or higher gelatinization is unacceptable, while moderate gelatinization indicates good quality rice for cooking and eating purposes. Advanced rice lines (AL-18 and AL-29) were indicated intermediate GT, which reveals to be considered good quality rice for both cooking and eating. Likewise, advanced lines such as AL-33 and 44 showed higher performance than the check varieties in rice, while lower performance was also observed in AL-42 line[23]. Moreover, the L/B ratio of those rice lines is significantly influenced the HRR and expansion of volume traits among all other quality traits. It reveals that HRR and the nature of rice expansion depend on the length and breadth of rice lines.

CONCLUSION

Rice is the staple food of Bangladesh. To fulfil the demand of a vast population and establish food security, it is indispensable to introduce a wide yielding rice variety in Bangladesh. This small-scale study deals with only three advanced and two check varieties of rice. The findings of this study reveal that advanced line AL-29 has higher yield performance and better cooking and eating quality than other advanced lines. It showed that the AL-29 line can contribute significantly to the total rice production in Bangladesh. For a deeper understanding of cooking and eating quality, it is recommended to include all other chemical rice properties such as amylose content, amylopectin content, starch content, molecular analysis to understand the starch biosynthesis pathways and Quantitative Trait Locus (QTL) mapping in further studies.

SIGNIFICANCE STATEMENT

This study discovered the grain physio-chemical properties and yield potentiality of some rice varieties that can be beneficial for the selection of good variety and recommendations to the farmers. This study will help the researchers to uncover the critical areas of grain quality of these selected varieties that many researchers were not able to explore. Thus, a new theory on varietal selection may have arrived that can be applied for future study.

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