Screening out the early matured 'Boro Rice' genotype for Bangladesh condition based on their Physico-chemical characteristics and yields

Abstract: In Bangladesh conditions, the end of the Boro season begins floods and natural calamities and loses more rice in farmer's fields. If we can select early maturity genotypes for the Boro season, we can harvest our rice from the farmer's field before flooding or any other natural calamities. The study attempted to determine the short duration and high yielding rice genotype for Boro season in Bangladesh amongst the 13 Boro rice F6 lines by contrast with two (2) test varieties. Keeping in view this idea, the output of the genotypes studied, the relationship between different morpho-physio-chemical and yield-contributing characteristics between all the genotypes were investigated there under field and laboratory conditions. Among these 15 lines, G11 line showed better in the most yield contributing parameters. It is therefore concluded that the G11 genotype will be considered an appropriate line for the Boro season in Bangladesh.

Keywords: Screening, Physio-chemical properties, Yield, Genotype, Rice.

1. Introduction

Rice is one of the world's most important food crops, serving as a staple food for more than one-third of the world's population [1]. There are two different types of rice cultivated, viz. Asian (*Oryza sativa*) and African (*Oryza glaberrima*) rice. The 'Oryza' genus is divided into four species such as *Oryza sativa*, *Oryza ofcinalis*, Oryza ridelyi, and *Oryza granulata*. All members of the genus Oryza have n = 12 chromosomes. Rice ranks second to wheat amongst the most cultivated cereals throughout the world [2].

In Bangladesh, rice contributes to approximately 74% of the total cropped area [3]. Due to rice cultivation and total production, Bangladesh ranks fourth, after China, India and Indonesia [4]. The population of Bangladesh continues to grow by two million a year and may keep increasing by another 30 million within the next 20 years. Bangladesh will therefore require over 27.26 million tonnes of rice for 2020 but the average yield of rice is poor (4.34t ha^{-1}) in Bangladesh [5]. On the other hand, the rice production area is declining day by day due to high population pressures.

Rice occupies a unique position in many nations due to its importance in traditional diets and the main source of income for many people in the world. It is the basis of food security and is closely linked to Bangladesh's traditional culture and customs. The wide diversity of the environment in Bangladesh, mainly due to the significant variations in topographic and seasonal components, is reflected in the range of rice groups cultivated, i.e., Aus, transplanted (T.) Aman, broadcast (B.) Aman and Boro, including in the distribution of wild and weed races [6].

The Aus season is from March-April to July-August, T. Aaman from June-July to November-December and the Boro season from October-November to April-May. Boro rice has contributed a large part of the total production of rice in Bangladesh. During the Boro season, one-fourth of the total rice area is covered by Boro rice and one-third of total rice production [1].

In view of the above information, boro rice has a vast potential in Bangladesh. The end of the Boro season begins with floods and natural calamities and the loss of more rice in the farmers' fields. If we can select early maturation genotypes for the Boro season, we can harvest our rice from the farmer's field before flooding or any other natural calamity. It is therefore important to develop rice cultivars that are ideally suited to various boro rice-growing situations. Interval crosses and generation evaluations must be carried out to generate high yielding boro rice cultivars and to select early maturity and high yielding materials. The present study was therefore undertaken to identify the appropriate genotype based on their growth parameters, ~~physicochemical~~ and yield-contributing characteristics of selected boro rice genotypes.

2. Materials and Methods

2.1 Experimental site

The research study carried at the central farm, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, from December 2015 to May 2016. The experimental field was located at 90 ° 22 'E longitude and 23 ° 41' N latitude at an altitude of 8.2 ~~metres~~ above sea level. It was under the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) and its topsoil is clay loam in texture and ~~olive-gray w~~with common fine to medium distinct dark yellowish-brown mottles. The soil pH was 6.10; organic matter (0.84%); total N (0.46 %); exchangeable K (0.41meq/100g soil); available P (18.65µg g^{-1}); S (20.92µg g^{-1}); Fe (225µg g^{-1}); Zn, (4.55µg g^{-1}) and Mg (0.81µg g^{-1}).

2.2 Planting materials

There are 15 (Fifteen) rice genotypes used in this experiment. Among the fifteen rice genotypes, thirteen genotypes were F5 materials and two were controlled materials. Physically healthy seeds of these genotypes have been obtained from the Department of Genetics and Plant Breeding (SAU), Dhaka. The name and origin of these genotypes are shown in Table 1.

2.3 Germination of seed, Seedbed preparation, seedling raising, and transplanting

The collected seeds of all genotypes were soaked separately in a clothing bag for twenty-four (24) hours. Soaked seeds were taken out of the water and covered with straw and a gunny bag to raise the temperature to help the germination. After 72 hours, the seeds were properly germinated. Germinated seeds have been seeded in selected seed beds, and seedlings have been raised by maintaining regular intervals of irrigation and protection from birds and insects. Recommended fertilisers were used in the main field before final soil preparation and thirty (30) days old seedlings were planted in the main field followed by 25 cm × 20 cm plant spacing.

2.4 Data collection

All morphological, physiological and biochemical data were collected following the standard method and data was recorded from the following parameters:

2.4.1. Morphological

Days to flowering, days to maturity, total tillers/plant, number of effective tiller per plant, Panicle length (cm**)**, Filled grains number per panicle**,** Unfilled grains number per panicle, Number of unfilled grains per panicle, Total number of spikelet per panicle, Yield/plant and 1000 seeds weight (gm)

2.4.2. Physiological

2.4.2.1. Milling and grain appearance

Hulling (%), Milling outturn (%), Head rice recovery (%), Length/Breadth ratio of rough rice and Length/Breadth ratio of milled rice.

2.4.2.2.Cooking characteristics

Kernel Length/ Breadth ratio of cooked rice, Kernel elongation ratio,
Kernel elongation index, Water absorption (uptake) percentage, Volume expansion (%).

2.4.3. Biochemical

Protein (%), Amylose (%)

2.5 Experimental designs and data analysis

The experiments were designed in a randomised complete block design (RCBD). The data were calculated and the mean value was analyzed using a one-way variance analysis (ANOVA) using the Statistical Package for Social Sciences (SPSS) Software Version 20.0 (SPSS Inc., Chicago, IL, USA). Mean and standard error comparisons were determined by Duncan's multiple range tests at $p \leq 0.05$ significance level.

3. Results

3.1 Evaluation of the growth and yield performance of different f6 lines of boro rice

3.1.1 Days to 50 percent flowering

Days to 50 percent of the flowering of different F6 lines of rice differentiated significantly (Figure 1). The maximum days for 50 per cent of flowering (129.66 days) were recorded from G14 (BRRI dhan 29) which was the control variety and the other control variety was BRRI dhan 28(121.33), while the minimum days (117.33 days) were recorded from G11 (28 x 29 F6S2P4P3).

3.1.2 Days to maturity

Days to maturity of different F6 lines of Boro rice varied significantly (Figure 2). Among genotypes, the days to maturity ranged from 155 days to 138 days with a mean value of 144.17 days. Maximum days to maturity were found in genotype G14 (BRRI dhan 29). The G11 genotype (BRRI dhan 28 x BRRI dhan 29 F6 S2 P4 P3) had the shortest maturation period of 138 days, which is lower than the check variety BRRI dhan 29.

3.1.3 Plant height (cm)

In this study, the highest plant height (142.20 cm) was recorded from G4 (BR 21 x BRRI dhan28 F6S5P3P4) which was longer than their controls, such as BRRI dhan 29 (93.54 cm) and BRRI dhan 28 (100.52 cm) respectively. The minimum height of the plant was recorded from G14, which was checked. The rest of the population showed different plant heights (Table 2).

3.1.4 Total tillers per plant

Total tillers per plant of a different line of rice varied marginally (Table 2). The highest number of tiller per plant (17.83) was documented as G11 (BRRI dhan 28 X BRRI dhan 29 F6 S2 P4 P3), which was similar to G12 (17.40) and G15 (17.67). The minimum number (12.53) was observed in G4 (BR 21 x BRRI dhan 28 F6S5P3P4).

3.1.5 Effective tillers per plant

The comparative performance of F6 lines and the test variety for effective tillers per plant are shown in Table 2. Effective tillers per plant of different F6 lines of boro rice differentiated significantly (Table 2). The highest number of effective tillers per plant (17.20) was documented from G11 (BRRI dhan 28 X BRRI dhan 29 F6 S2 P4 P3) which was statistically similar to G12, G15. The lowest number (12.07) of effective tiller was found in G4 (BR 21 x BRRI dhan 28 F6 S5 P3 P4). The rest of the population had shown different effective tillers per plant.

3.1.6 Panicle length (cm)

The length of the panicle was significantly varied across the different F6 lines of Boro rice (Table 2). The maximum panicle length (27.90 cm) was recorded from G11 (BRRI dhan 28 X BRRI dhan 29 F6 S2 P4 P3), which was higher than BRRI dhan 28 (24.07 cm) & BRRI dhan 29 (23.17 cm) and the minimum panicle length (20.91 cm) was recorded from G6 (BR 21 x BRRI dhan 29 F6S6P2P3).

3.1.7 Primary branches per panicle

From the mean tabulated value, the maximum primary branches for each panicle was performed besides G11 (14.26) while the minimum primary branches per panicle was documented for G2 (9.26) (Table 3). The rest lines had different primary branches for each panicle.

3.1.8 Secondary branches per panicle

Among the 15 genotypes, the maximum secondary branches per panicle was reported to G11 (40.10), while the minimum secondary branches per panicle was demonstrated in G2 (26.50) which was quite similar to G1 (26.76) (Table 3) and their checks were BRRI dhan 29 (32.20) and BRRI dhan 28 (30.23).

3.1.9 Spikelet per panicle

Spikelet per panicle of different F6 lines of rice differed significantly (Figure 3). The maximum spikelet per panicle (214.66) was documented in G7, while the minimum (152.93) was reported in G1. Genotypes G4, G7, G10, G11, G12 were shown to have a higher number of spikelet per plant than controls G14 (176.56) and G15 (187.93).

3.1.10 Filled grains per panicle

The maximum filled grains were recorded in G11 (195.96) which was higher than their checks in G14 (176.56) and G15 (187.93) respectively (Figure 4). The remainder of the population displayed a different number of grains filled per panicle.

3.1.11 Unfilled grains per panicle

The highest unfilled grains were recorded from G1 (90.06) while the lowest unfilled grains were documented in G11 (12.76). The rest of genotypes exhibited different unfilled grains number in each panicle (Table 3).

3.1.12 Yield per plant (g)

The highest amount of yield (54.86 g) was documented from genotype G11 which was higher than their checks BRRI dhan 29 and BRRI dhan 28 had a 40.06g and 46.26g yield per plant respectively whereas the minimum (20.53 g) was recorded from G1 (Figure 5). Rest of the population showed different yield per plant.

3.1.13 1000 Seed weight (g)

The maximum weight of 1000 seeds (26.41) was recorded from G11, while the minimum weight of 1000 seeds (21.25) was reported from G7 and had been statistically similar to G1 (21.90), G2 (21.63), G10 (21.99) and G14 (21.40) (Table 3).

3.2 Correlations analysis

For indirect selection purposes the correlation analysis of agronomic traits can be used as a selection tool. Correlation studies can easily explain the plant breeder's yield components during the selection process. Table 4 displays most of the variables, including the days to maturity (R^2 = 0.778), number of effective tiller (R^2 = 0.978), length of panicle (R^2 = 0.573), primary branches/panicle (R^2 = 0.635), secondary branches/panicle (R^2 = 0.659), spikelet per panicle (R^2 = 0.409), filled grains per panicle (0.768), yield per plant (R^2 = 0.968) and 1000 seed weight (0.709) showed a strong correlation to the key characteristics of the yield. A negative correlation was documented on plant height (R2 = -0.311), a number of the tiller (R2 = -0.328) and unfilled grains per panicle (R2 = -0.776).

3.3 Milling and grain appearance/quality characters of f6 line of boro rice

The word paddy or rough rice is the same for paddy, or rice that retains its husk after threshing, and brown rice or husked rice is the paddy from which the husk was removed. Another milling process removes the bran for the production of milled rice. The rice's quality is characterized by its grain appearances, cooking consistency and nutritional value.

3.3.1 Kernel length, breadth and their ratio of rough rice

Kernel length breadth and their ratio of rough rice for different F6 lines of boro rice varied significantly (Table 5). The longest rough rice was observed in G11(9.92 mm), which was longer than both checks BRRI dhan 29 (8.46 mm) and BRRI dhan 28 (9.04 mm) whereas the shortest rough length (5.84 mm) was found in G6 (7.72). Genotype G9, G12, and G13 also were longer than checks. G1 and G5 were statistically identical with BRRI dhan 29. The highest breadth of rough rice (2.95mm) was observed in G11, which was higher than both checks, as their checks BRRI dhan 29 and BRRI dhan 28 had 2.42mm and 2.47 mm respectively, whereas the lowest breadth (2.36 mm) was recorded in G7. Except for G7, all lines showed higher breadth than checks. The highest (5.08) length and breadth ratio was observed in G7 (3.69) and the lowest ratio (2.81) from G6. Genotype G9 were statistically similar with G15 and G2, G3 and G14 were statistically similar. Rest genotypes showed different L/B ratio of rough rice The remaining genotype showed different Length, Breath ratio in rough rice (Table 5).

3.3.2 Kernel length, breadth and their ratio of uncooked rice

In various F6 Boro rice lines, kernel length, breadth, and their ratio of uncooked rice were statistically significant (Table 6). The maximum kernel length (7.13 mm) was found in G11, which was higher than their controls such as 6.46 mm and 6.72 mm respectively for BRRI dhan 29 and BRRI dhan 28. The lowest length of kernel (5.47 mm) was found in G6. The highest breadth of uncooked rice (2.47 mm) was observed in G6, which was statistically identical with G5 (2.45 mm), whereas the lowest breadth (2.06 mm) was recorded in BRRI dhan 29. The BRRI dhan 28 had 2.15 mm that was statistically similar to G2, G7 and G1, G4, G10, and G12. Genotype G13 (3.31) reported the highest length and breadth ratio of uncooked rice, which was statistically comparable with G14 and G15 and the lowest ratio from G3 (2.34).

3.4 Cooking consistency of rice

3.4.1 Kernel length, breadth, and their ratio of cooked rice

Kernel length, breadth and their ratio (Table 7) of cooked rice varied significantly in different F6 lines. The longest kernel of cooked rice (11.05 mm) was recorded from G1, which was similar to G10 (10.70 mm) and the shortest (7.27 mm) from G6, which was statistically identical with G2 (7.55 mm), G12 (7.54 mm) and BRRI dhan 29 (7.36 mm). Rice grains absorb water during cooking and increase in volume by increasing length or breadth alone or length and breadth both. The highest breadth was observed in G10 (3.74 mm) which was statistically identical with G3 (3.38 mm), G4 (3.31 mm), G5 (3.65 mm), G6 (3.29 mm) and G11 (3.40 mm), while the lowest breadth was found from G12 (2.41 mm). The highest kernel length and breadth ratio (3.50) was reported from G1 and the lowest ratio (2.09) from G6, since their checks were 2.85 and 3.04 respectively from BRRI dhan 29 and BRRI dhan 28.

3.4.2 Kernel elongation ratio

Kernel elongation ratio varied significantly for different F6 rice lines (Table 7). Genotype G1 recorded the highest kernel elongation ratio (1.77) which was statistically similar to G10 (1.74) and the lowest recorded ratio (1.13) of BRRI dhan 29 which was statistically similar to G9 (1.15), G12 (1.14) and BRRI dhan 28(1.15). The maximum lines showed a greater proportion than checked.

3.4.3 Kernel elongation index

Kernel elongation index for different F6 lines of rice varied significantly (Table 8). The highest kernel elongation index (1.28) was recorded from G1which was statistically similar to G8 (1.13), G10 (1.21) and G12 (1.18) whereas the lowest ratio (0.72) was recorded from G13. Two checks BRRI dhan 29 and BRRI dhan 28 had 0.97 and 0.89 respectively.

3.4.4 Volume expansion (%)

Another significant indicator of consumer choice is the expansion of volume of kernels during cooking. Volume expansion for various new F6 boro rice lines varied considerably (Table 8). The maximum volume expansion (83.50 %) was recorded from G11 and the minimum (16.35 %) recorded from G13 was statistically comparable to G9 and controls were 20.07 % from BRRI dhan 29 and 20.93 % from BRRI dhan 28.

3.4.5 Water absorption (%)

Water absorption for different F6 lines of rice varied significantly (Table 8). The highest water absorption (470.33 %) was documented from G7 and the lowest (140.11 %) was observed in G11. The two checks BRRI dhan 29 and BRRI dhan 28 had 179.84% and 155.99%. Genotype G4, G9, G12 were similar to BRRI dhan 28. Rest of the populations showed different water absorption (%).

3.4.6 Hulling (%)

Rice hulling percentage differed significantly for different boro rice lines of F6 (Table 8). The G11 reported maximum (73.75) hulling (%), and G2 recorded minimum (68.37) hulling (%), which was statistically similar to G8. The resemblance between G1 and G5 has been established. The remainder of the genotype displayed hulling (%) differently.

3.4.7 Milling outturn (%)

The milling outturn represents the actual output of the consumable product. Strong milling efficiency requires a fast recovery of the whole kernel and less rice breakage. Although milling recovery as a whole depends primarily on the quality of the hull varying from 18 to 26 per cent and the nature of the aleurone area. Rice milling output for different F6 rice line was varied significantly (Figure 6). Genotype G3 recorded the maximum milling outtturn (65.84 %), which was statistically identical to G6, G11, and G13, whereas G8 recorded the lowest (61.05 %).

3.4.8 Head rice recovery (%)

The Head rice recovery (HRR) differed significantly for various F6 boro rice lines (Figure 7). The maximum head rice recovery in G9 was reported (61.63%), which was statistically the same as G11, G12, G13 and G14, while G3 (44.63%) was shown as the lowest.

3.5 Biochemical properties

3.5.1 Protein (%)

From a nutritional point of view, protein content is a key factor in rice. The protein content of the different genotypes ranges from 7.03 to 9.53 %. The protein content of different F6 lines of rice varied significantly

(Figure 8). The highest protein (9.63 %) was from G4, which was statistically identical to G1 (9.53 %) and the lowest (7.03 %) from BRRI dhan 29, which was statistically related to G6 (7.13 %) and G9 (7.20 %). The two checks BRRI dhan 29 had 7.03% and BRRI dhan 28 had 8.50 % which was statistically close to G2 (8.60 percent). Genotype G5 and G8 also had higher protein percentage and moderate protein was present in G3, G7, G10, G11.

3.5.2 Amylose (%)

Amylose content of the different F6 lines varied significantly and ranges from 23.53 to 27.5% (Figure 9). The highest amylose (27.5%) was documented from BRRI dhan 29 and the lowest (23.53%) were in G10 which was statistically similar to G4 (24%). The two checks BRRI dhan 29 and BRRI dhan 28 had 27.50% and 26.80% respectively.

3.2. Figures, Tables and Schemes

Table 1. List of the genotypes used in the experiment with their source

Sl. No.	Designation	Genotypes	Source
1	(G1)	BR 21 x BR 26 F6 S6 P7 P7	
2	(G2)	BR 21 X BR 26 F6 S6 P3 P5	
3	(G3)	BR 21 X BRRI dhan 28 F6 S5 P1 P2	
4	(G4)	BR 21 X BRRI dhan 28 F6 S5 P3 P4	
5	(G5)	BR 21 X BRRI dhan 29 F6 S6 P6 P1	
6	(G6)	BR 21 X BRRI dhan 29 F6 S6 P2 P3	GEPB, SAU
7	(G7)	BR 24 X BR 26 F6 S6 P4 P8	
8	(G8)	BR 24 X BRRI dhan 28 F6 S10 P6 P10	
9	(G9)	BR 26 X BRRI dhan 28 F6 S1 P9 P5	
10	(G10)	BR 26 X BRRI dhan 29 F6 S6 P3 P3	
11	(G11)	BRRI dhan 28 X BRRI dhan 29 F6 S2 P4 P3	
12	(G12)	BRRI dhan 28 X BRRI dhan 36 F6 S7 P8 P5	
13	(G13)	BRRI dhan 29 X BRRI dhan 36 F6 S5 P10	
14	(G14)	BRRI dhan 29	BRRI,
15	(G15)	BRRI dhan 28	Gazipur

Note: GPB= Department of Genetics and Plant Breeding, SAU= Sher-e-Bangla Agricultural University, BRRI= Bangladesh Rice Research Institute

Table 2: Performance of growth and yield contributing characters of different F6 lines of Boro rice

Genotype	Plant height (cm)	Number of total tillers/Plant	Number of effective tillers/Plant	Panicle length (cm)
G1	108.57 ± 0.40^{de}	16.60 ± 0.84^{abc}	16.16 ± 0.74^{ab}	23.17 ± 0.74^{d-f}
G2	111.54 ± 0.43^{c-e}	16.13 ±0.19 a-d	15.66 ±0.27 a-c	22.48 ± 0.14^{f}
G3	124.88 ± 3.25^{b}	14.57 ± 0.12^{de}	13.80 ± 0.39^{c-e}	24.77 ± 0.38^{b}
G4	142.20 ± 1.52^{a}	12.53 ± 0.03^{f}	12.07 ± 0.08^{e}	24.35 ± 0.09^{bc}
G5	113.44 ± 1.37^{cd}	15.23 ± 0.41^{cd}	14.40 ± 0.78^{b-d}	22.99 ± 0.04^{ef}
G6	105.45 ± 2.50^{e-g}	12.97 ± 0.58^{ef}	12.63 ± 0.46^{de}	20.91 ± 0.39^{g}
G7	115.44 ± 5.07^{c}	15.13 ± 0.26^{cd}	14.76 ± 0.27^{bc}	24.06 ± 0.15^{b-d}
G8	107.02 ± 1.48^{d-f}	12.97 ± 0.52^{ef}	12.63 ± 0.61^{de}	23.22 ± 0.57^{d-f}
G9	100.18 ± 0.58^{g}	16.80 ± 0.46^{a-c}	16.26 ± 0.54^{ab}	23.57 ± 0.22^{c-e}
G10	116.70 ± 1.27^{c}	16.80 ± 1.08^{a-c}	16.16 ± 1.24^{ab}	22.54 ± 0.07^{f}
G11	100.84 ± 0.62^{fg}	17.83 ± 0.28^{a}	16.86 ± 0.82^{a}	27.90 ± 0.08^{a}
G12	107.29 ± 3.92^{d-f}	17.40 ± 0.68^{ab}	17.20 ± 0.17^{a}	24.32 ± 0.37^{bc}
G13	99.95 ± 0.39^{g}	15.90 ± 0.87^{b-d}	15.73 ± 0.81^{a-c}	23.36 ± 0.39^{d-f}
G14	93.54 ± 0.68^{h}	14.47 ± 0.48^{de}	13.86 ± 0.51^{c-e}	23.17 ± 0.17^{d-f}
G15	100.52 ± 0.57^{fg}	17.67 ± 0.37^{a}	16.93 ± 0.28^{a}	24.07 ± 0.05^{b-d}

The data represent the mean values ± standard error. Different letter (s) corresponds to significant differences at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT).

Table 3: Performance of yield contributing characters and yield of F6 lines of Boro rice

Genotype	Number of primary Branches/ Panicle	Number of secondary Branches/ Panicle	Number of unfilled grains/ Panicle	1000 seeds weight (gm)
G1	9.60 ± 0.11[fg]	26.76 ± 0.82[g]	90.06 ±4.89[a]	21.90 ± 0.44[f]
G2	9.26 ± 0.12 [g]	26.50± 0.36[g]	25.03 ± 2.35[cd]	21.63 ± 0.22[f]
G3	11.33 ± 0.35[bc]	30.76 ± 1.17[d-f]	48.76 ± 0.21[b]	25.03 ± 0.27[bc]
G4	11.40 ± 0.12[bc]	37.46 ± 0.49[ab]	41.86 ± 2.33[b]	23.90 ± 0.29[cd]
G5	12.06 ± 0.48[b]	30.96 ± 1.12[d-f]	22.83 ± 5.80[d]	24.14 ± 0.35[cd]
G6	10.00 ± 0.17[e-g]	34.66 ± 1.49[b-d]	16.03 ± 0.19[de]	23.60 ± 0.48[de]
G7	9.43 ± 0.18[fg]	33.60 ± 1.94[c-e]	18.90 ± 2.51[de]	21.25 ± 0.12[f]
G8	10.43 ± 0.15[de]	30.93 ± 0.21[d-f]	22.83 ± 0.44[d]	22.44 ± 0.09[ef]
G9	9.50 ± 0.32[fg]	29.60 ± 1.18[fg]	16.26 ± 1.50[de]	23.86 ± 0.73[cd]
G10	10.86 ± 0.28[cd]	28.56 ± 1.62[fg]	16.73 ± 0.58[de]	21.99 ± 0.21[f]
G11	14.26 ± 0.23[a]	40.10 ± 2.16 [a]	12.76 ± 0.27[e]	26.41 ± 0.69[a]
G12	11.6 ± 0.12[b]	36.10 ± 0.44[bc]	33.06 ± 5.04[c]	24.30 ± 0.02[b-d]
G13	10.03 ± 0.29[e-g]	30.86 ± 0.19[d-f]	15.13 ± 4.29[de]	25.47 ± 0.57[ab]
G14	10.16 ± 0.18[d-f]	32.20 ± 0.49[d-f]	17.06 ± 2.57[de]	21.40 ± 0.50[f]
G15	9.46 ± 0.09[fg]	30.23 ± 1.65[e-g]	21.66 ± 2.11[de]	22.52 ± 0.16[ef]

The data represent the mean values ± standard error. Different letter (s) corresponds to significant differences at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT).

Table 4. Correlation coefficients among the agronomic traits using genotypes means

Characters	DM	PH	NT	NET	LP	NPBp	NSBP	TSp	NFGp	NUFGp	Yield/P	TSW
DM	.778**	-.009	-.057	-.065	-.094	-.450**	-.133	-.090	-.028	-.044	-.164	-.553**
PH		-.311*	-.064	-.078	-.010	-.204	-.105	-.218	-.326*	.283	-.329*	-.310*
NT			-.328*	-.356*	-.145	.627**	.237	.315*	-.017	.336*	-.134	.359*
NET				.978**	-.142	-.393**	-.429**	-.076	-.031	-.029	.236	-.225
LP					.573**	-.389**	-.415**	-.092	-.051	-.014	.216	-.195
NPBp						.635**	.267	.361*	.095	.209	.065	.507**
NSBp							.659**	.364*	.141	.141	.260	.622**
TSp								.409**	.385**	-.187	.538**	.414**
NFGp									.768**	-.192	.470**	-.033
NUFGp										-.776**	.700**	-.047
Yield/P											.968**	.199
TSW												.709**

**. Correlation is significant at the 0.01 level; *. Correlation is significant at the 0.05 level.

Indicators: DM= Days to maturity; PH= Plant height; NT= Number of tiller; NET= Number of effective tiller; LP= Length of Panicle; NPBp= Number of primary branches/Panicle; NSBp= Number of secondary branches/Panicle; TSp= Total spikelet/Panicle; NFGp= Number of filled grain/Panicle; NUGp= Number of unfilled grain/Panicle; TSW= 1000 seed weight

Table 5: Performance of Milling and Grain quality of F6 lines of Boro rice

Genotype	Kernel length of rough rice	Kernel breadth of rough rice	Kernel Length, breadth ratio of rough rice
G1	$8.48 \pm 0.04^{d-f}$	$2.61 \pm 0.05^{b-e}$	3.25 ± 0.05^{d}
G2	$8.29 \pm 0.09^{e-g}$	$2.53 \pm 0.07^{c-g}$	3.27 ± 0.04^{cd}
G3	8.97 ± 0.14^{bc}	2.70 ± 0.04^{bc}	3.32 ± 0.02^{cd}
G4	8.74 ± 0.26^{cd}	$2.68 \pm 0.05^{b-d}$	3.26 ± 0.05^{cd}
G5	$8.37 \pm 0.12^{d-f}$	$2.59 \pm 0.03^{b-f}$	3.23 ± 0.04^{de}
G6	7.72 ± 0.11^{h}	2.75 ± 0.17^{b}	2.81 ± 0.06^{f}
G7	$8.72 \pm 0.11^{c-e}$	2.36 ± 0.01^{g}	3.69 ± 0.10^{a}
G8	7.91 ± 0.13^{gh}	$2.56 \pm 0.02^{c-f}$	3.08 ± 0.23^{e}
G9	9.13 ± 0.09^{bc}	$2.51 \pm 0.03^{d-g}$	3.64 ± 0.08^{ab}
G10	8.28 ± 0.04^{fg}	2.72 ± 0.02^{bc}	3.05 ± 0.02^{ef}
G11	9.92 ± 0.29^{a}	2.95 ± 0.06^{a}	3.36 ± 0.06^{c}
G12	9.05 ± 0.08^{bc}	$2.60 \pm 0.02^{b-f}$	3.48 ± 0.06^{bc}
G13	9.28 ± 0.05^{b}	$2.51 \pm 0.05^{d-g}$	3.50 ± 0.16^{b}
G14	$8.46 \pm 0.04^{d-f}$	2.42 ± 0.04^{fg}	3.50 ± 0.03^{b}
G15	9.04 ± 0.11^{bc}	$2.47 \pm 0.11^{e-g}$	3.66 ± 0.02^{ab}

The data represent the mean values ± standard error. Different letter (s) corresponds to significant differences at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT).

Table 6: Performance of Milling and Grain quality of F6 lines of Boro rice

Genotype	Kernel length of uncooked rice	Kernel breadth of uncooked rice	Kernel Length, breadth ratio of uncooked rice
G1	6.22 ± 0.01^{de}	2.25 ± 0.01^{a-d}	2.76 ± 0.06 ^{c}
G2	6.22 ± 0.10^{de}	2.10 ± 0.16^{b-d}	2.96 ± 0.04^{bc}
G3	6.48 ± 0.04^{cd}	2.34 ± 0.02^{a-c}	2.34 ± 0.04^{d}
G4	6.41 ± 0.24^{cd}	2.22 ± 0.02^{a-d}	2.88 ± 0.05^{bc}
G5	6.02 ± 0.14^{ef}	2.45 ± 0.06^{a}	2.45 ± 0.01^{cd}
G6	5.47 ± 0.02^{g}	2.47 ± 0.02^{a}	2.21 ± 0.03^{de}
G7	6.47 ± 0.01^{cd}	2.13 ± 0.06^{b-d}	3.04 ± 0.08^{bc}
G8	5.79 ± 0.01^{fg}	2.37 ± 0.01^{ab}	2.44 ± 0.02^{cd}
G9	6.63 ± 0.03^{bc}	2.15 ± 0.02^{b-d}	3.08 ± 0.03^{b}
G10	6.19 ± 0.01^{de}	2.26 ± 0.01^{a-d}	2.74 ± 0.17^{c}
G11	7.13 ± 0.15^{a}	2.33 ± 0.03^{a-c}	3.06 ± 0.05^{bc}
G12	6.61 ± 0.13^{bc}	2.25 ± 0.01^{a-d}	2.92 ± 0.07^{bc}
G13	6.89 ± 0.12^{ab}	2.08 ± 0.02^{cd}	3.31 ± 0.09^{a}
G14	6.46 ± 0.16^{cd}	2.06 ± 0.23^{d}	3.13± 0.05^{ab}
G15	6.72 ± 0.12^{bc}	2.15 ± 0.02^{b-d}	3.13 ± 0.23^{ab}

The data represent the mean values ± standard error. Different letter (s) corresponds to significant differences at p≤0.05 by Duncan's Multiple Range Test (DMRT).

Table 7: Performance of Grain quality of F6 lines of Boro rice

Genotype	Kernel length of cooked rice	Kernel breadth of cooked rice	Kernel Length, breadth ratio of cooked rice	Kernel elongation ratio
G1	11.05 ± 0.02a	3.18 ± 0.03^{bc}	3.50 ± 0.03^{a}	1.77 ± 0.01^{a}
G2	7.55 ± 0.01f	3.23 ± 0.07^{bc}	2.35 ± 0.05^{ef}	1.21 ± 0.02^{fg}
G3	9.07 ± 0.03b-d	$3.38 \pm 0.09^{a-c}$	2.67 ± 0.07^{de}	$1.40 \pm 0.01^{c-e}$
G4	9.53 ± 0.01bc	$3.31 \pm 0.08^{a-c}$	$2.94 \pm 0.07^{b-d}$	$1.33 \pm 0.02^{c-f}$
G5	9.74 ± 0.10b	3.65 ± 0.11^{ab}	2.68 ± 0.04^{de}	1.62 ± 0.05^{b}
G6	7.27 ± 0.06f	$3.29 \pm 0.04^{a-c}$	2.09 ± 0.17^{f}	$1.32 \pm 0.01^{d-f}$
G7	8.75 ± 0.09cd	3.18 ± 0.03^{bc}	2.75 ± 0.01^{cd}	$1.35 \pm 0.01^{c-e}$
G8	8.54 ± 0.68de	3.12 ± 0.12^{c}	2.78 ± 0.32^{cd}	1.47 ± 0.11^{c}
G9	7.65 ± 0.02ef	2.65 ± 0.02^{d}	$2.89 \pm 0.03^{b-d}$	1.15 ± 0.01^{g}
G10	10.70 ± 0.17a	3.74 ± 0.3^{a}	$2.89 \pm 0.02^{b-d}$	1.74 ± 0.01^{a}
G11	9.24 ± 0.93b-d	$3.40 \pm 0.18^{a-c}$	2.72 ± 0.13^{cd}	1.43 ± 0.09^{cd}
G12	7.54 ± 0.03f	2.41 ± 0.01^{d}	3.14 ± 0.02^{b}	1.14 ± 0.01^{g}
G13	8.75 ± 0.05cd	3.21 ± 0.52^{bc}	2.36 ± 0.02^{ef}	$1.26 \pm 0.01^{e-g}$
G14	7.36 ± 0.04f	2.57 ± 0.02^{d}	$2.85 \pm 0.01^{b-d}$	1.13 ± 0.02^{g}
G15	7.77 ± 0.02ef	2.56 ± 0.01^{d}	3.04 ± 0.02^{bc}	1.15 ± 0.02^{g}

The data represent the mean values ± standard error. Different letter (s) corresponds to significant differences at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT).

Table 8: Performance of Grain quality of F6 lines of Boro rice

Genotype	Kernel elongation Index	Volume expansion (%)	Water Absorption (%)	Hulling (%)
G1	1.28 ±0.02 ^{a}	40.54 ± 0.57^{e}	315.81 ± 34.02^{b}	70.95 ± 0.25^{de}
G2	0.85 ± 0.03^{ef}	29.62 ± 0.25^{h}	230.87 ± 3.25^{cd}	68.37 ± 0.79^{f}
G3	0.96 ± 0.01^{c-e}	28.31 ± 0.21^{i}	243.33 ± 19.15^{c}	71.36 ± 0.38^{b-e}
G4	0.91 ± 0.03^{de}	34.68 ± 0.05^{f}	171.33 ± 3.55^{ef}	70.73 ± 0.30^{e}
G5	1.09 ± 0.02^{b-d}	54.01 ± 0.08^{d}	353.75 ± 0.91^{b}	71.04 ± 0.70^{de}
G6	0.94 ± 0.08^{c-e}	55.63 ± 0.32^{c}	223.50 ± 1.45^{cd}	72.53 ± 0.37^{b}
G7	0.90 ± 0.03^{de}	20.91 ± 0.05^{j}	470.33 ± 32.13^{a}	71.59 ± 0.32^{b-e}
G8	1.13 ± 0.12^{a-c}	33.78 ± 0.51^{g}	188.68 ± 2.40^{de}	67.97 ± 0.16^{f}
G9	0.91 ± 0.01^{de}	16.84 ± 0.10^{l}	155.79 ± 6.02^{f}	71.12 ± 0.58^{c-e}
G10	1.21 ± 0.08^{ab}	57.66 ± 0.38^{b}	321.00 ± 9.81^{b}	72.16 ± 0.13^{b-d}
G11	0.99 ± 0.03^{c-e}	83.50 ± 0.28^{a}	140.11 ± 2.80^{f}	73.75 ± 0.15^{a}
G12	1.18 ± 0.11^{ab}	20.81 ± 0.11^{jk}	167.66 ± 10.96^{ef}	70.23 ± 0.01^{e}
G13	0.72 ± 0.03^{f}	16.35 ± 0.21^{l}	253.49 ± 7.26^{c}	72.41 ± 0.23^{bc}
G14	0.97 ± 0.02^{c-e}	20.07 ± 0.04^{k}	179.84 ± 4.68 ^{ef}	70.32 ± 0.68^{e}
G15	0.89 ± 0.05^{e}	20.93 ± 0.06^{j}	155.99 ± 3.54^{ef}	70.74 ± 0.13^{e}

The data represent the mean values ± standard error. Different letter (s) corresponds to significant differences at p≤0.05 by Duncan's Multiple Range Test (DMRT).

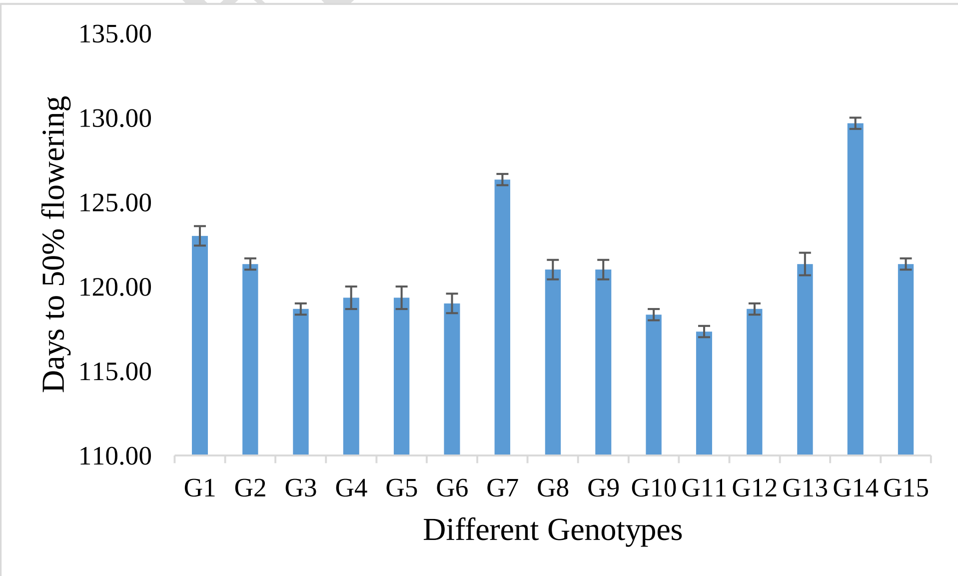

Figure 1. Days of 50% flowering on different F6 lines of Boro rice

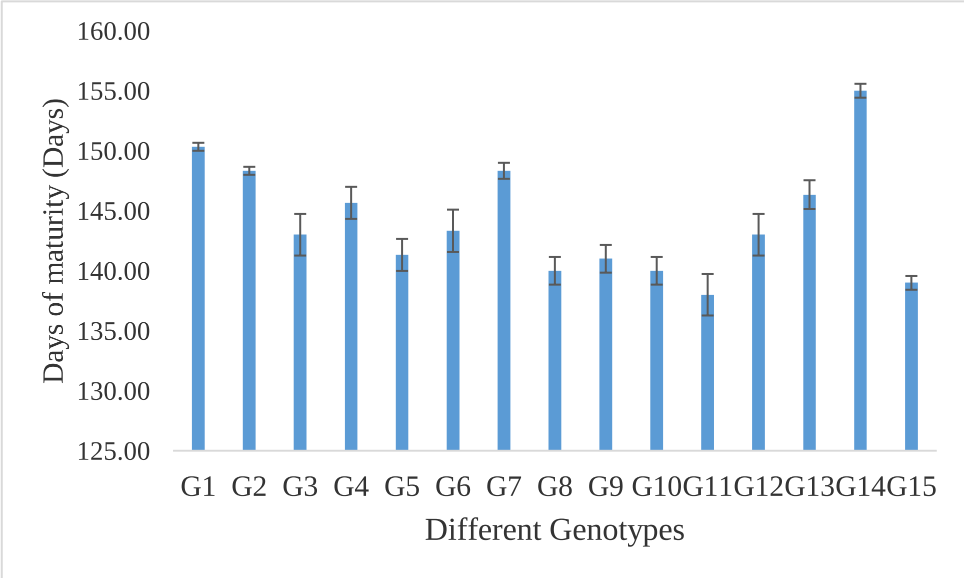

Figure 2. Days of maturity on different F6 lines of Boro rice

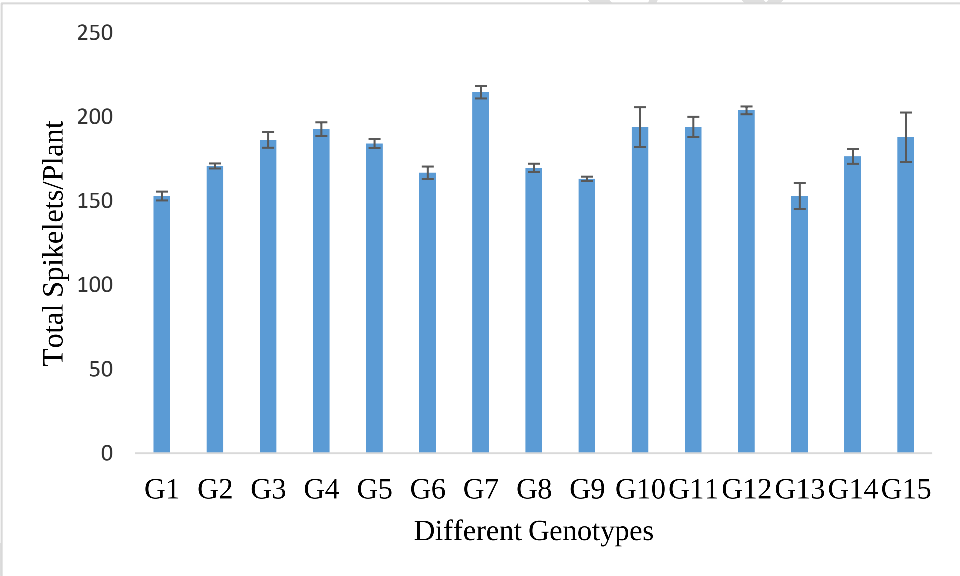

Figure 3. Total Spikelet/Plant on different F6 lines of Boro rice

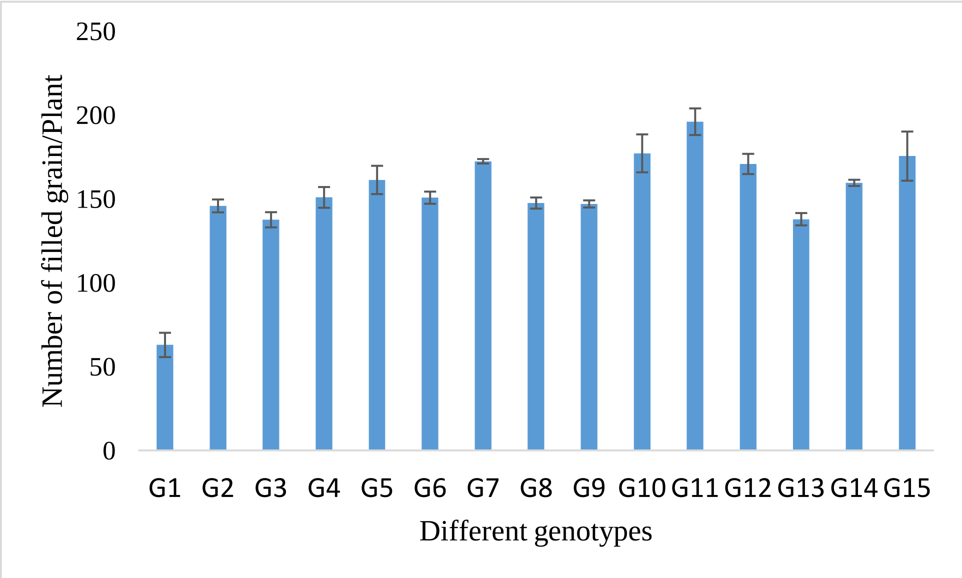

Figure 4. Number of filled grain/Plant on different F6 line of Boro rice

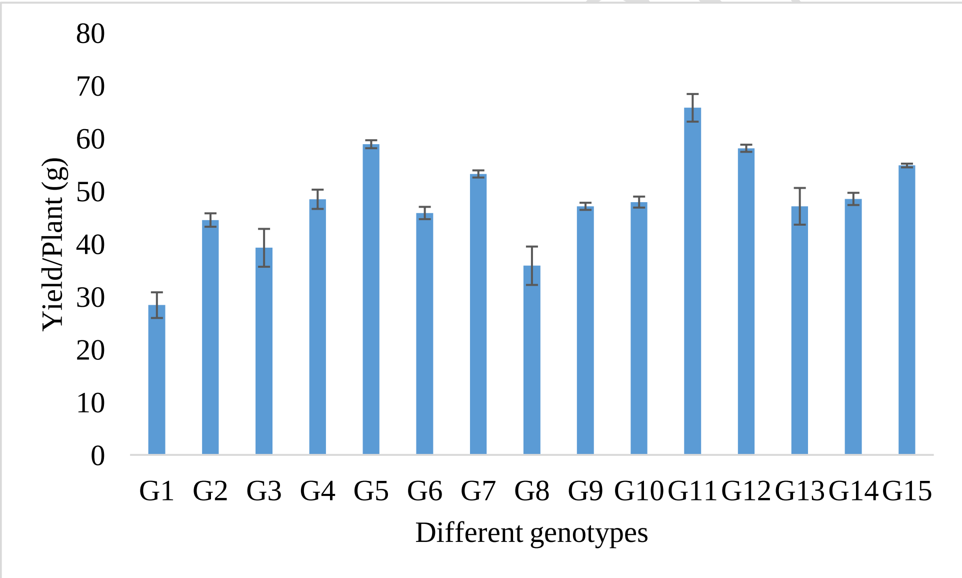

Figure 5. Yield per plant on different F6 line of Boro rice

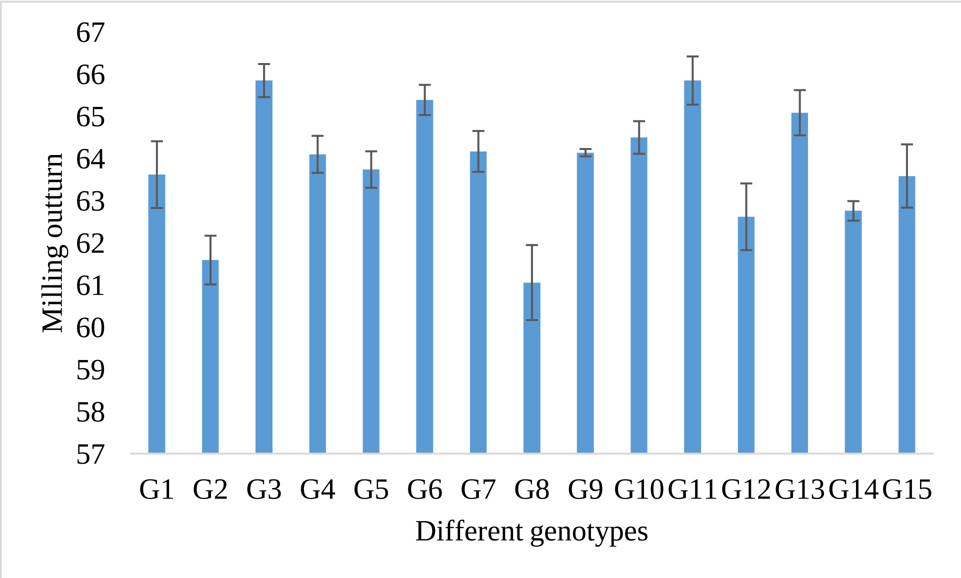

Figure 6. Milling outturn on different F6 lines of Boro rice

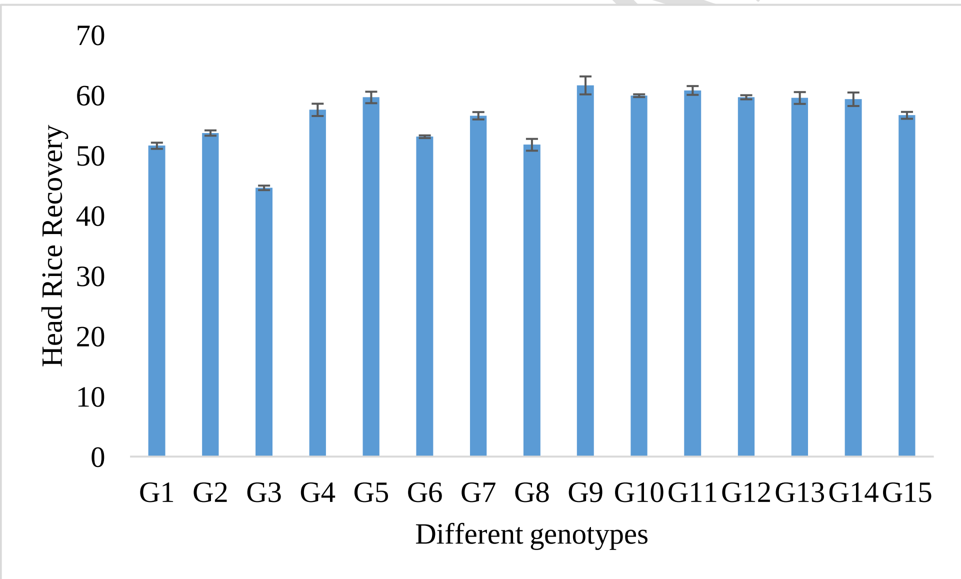

Figure 7. Head Rice Recovery on different F6 lines of Boro rice

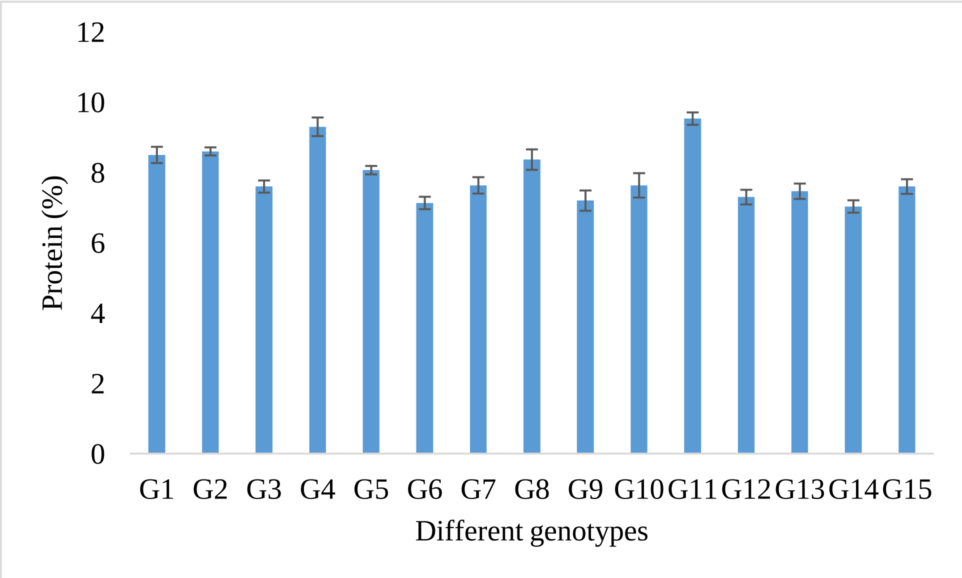

Figure 8. Protein (%) of different F6 lines of Boro rice

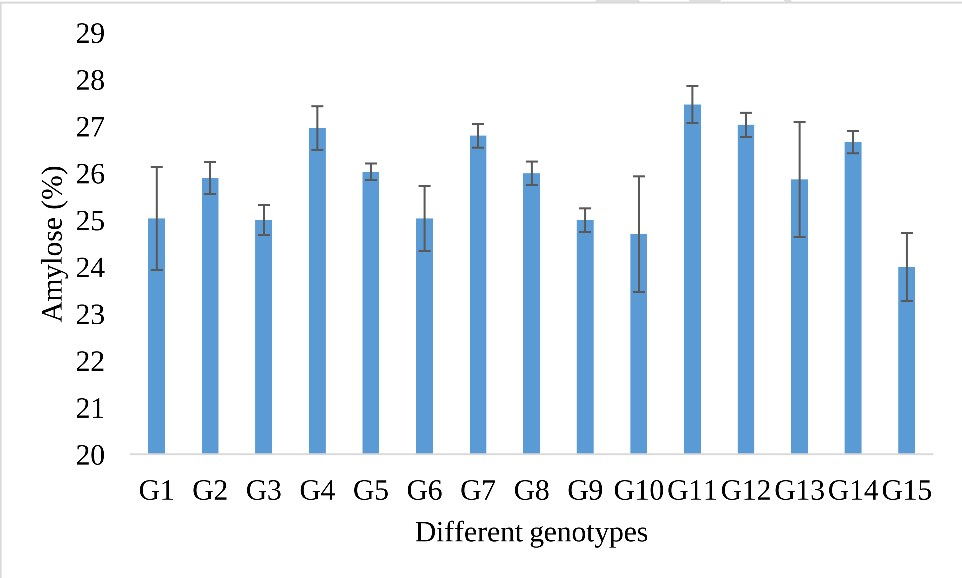

Figure 9. Amylose (%) on different F6 lines of Boro rice

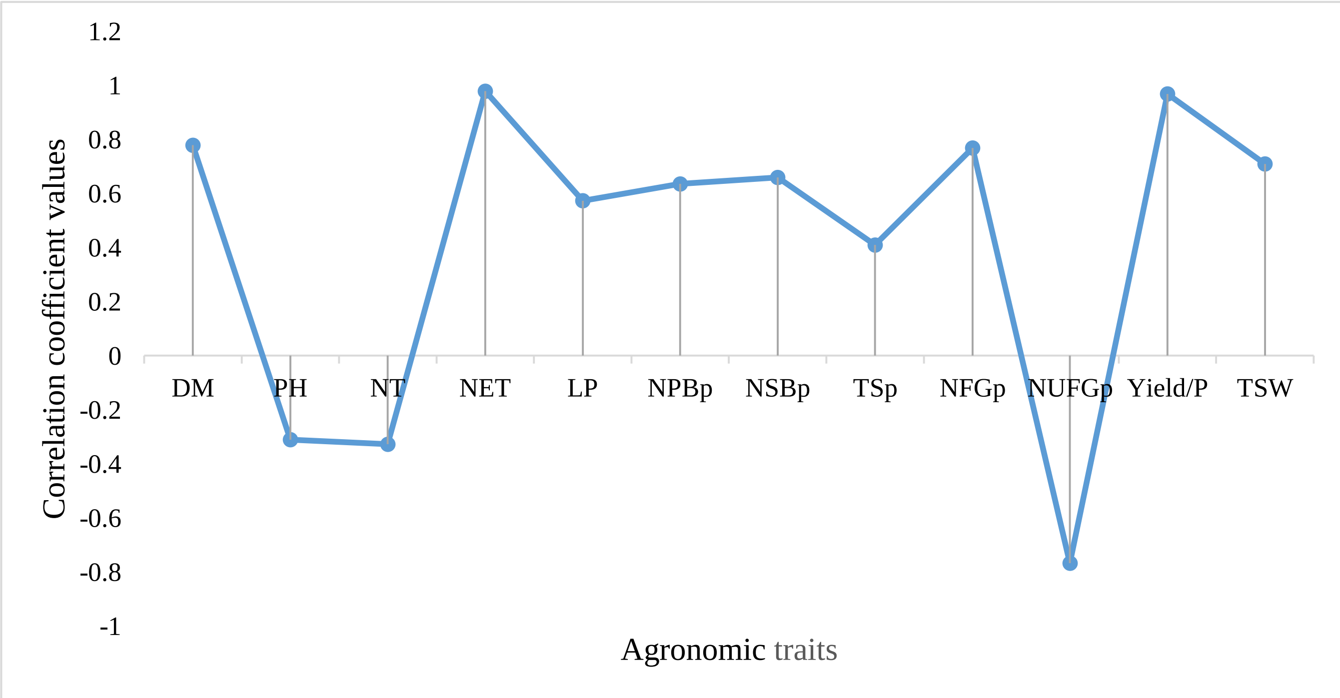

Figure 10. Correlation coefficients between different agronomic traits and grain yield. Indicators: DM= Days to maturity; PH= Plant height; NT= Number of tiller; NET= Number of effective tiller; LP= Length of Panicle; NPBp= Number of primary branches/Panicle; NSBp= Number of secondary branches/Panicle; TSp= Total spikelet/Panicle; NFGp= Number of filled grain/Panicle; NUGp= Number of unfilled grain/Panicle; TSW= 1000 seed weight

4. Discussion

In the past, several researchers suggested that high numbers of tillers are the source of greater yields [7-10]. The Author [11] reported that lower tillering habit (6-10 tillers / plant) would yield more than modern varieties of 20-25 tillers. The author also noted that only 14-15 of these tillers trigger small panicles and remain unproductive. Less tillering promotes flora and maturity and more unusual panicle size. The Author [12] notes that a smaller number of tillers also indicated that more heavy grain was low. Many researchers have recorded the positive relation between grain number of panicle and grain yield [13-15]. No major association between plant height and yield. This is in contrast [16] which had shown that plant height was associated positively and substantially with yield. In general, it is required to provide a low-grade high production of rice [17]. However, the number of effective tillers (NFT), the length of the panicle (PL), the number of primary branches, the number of secondary branches, the total spikelet, the number of grains filled and the weight of 1000 seeds showed a positive correlation with the yield. Grain unfilled showed a negative correlation. A negative association between productive tillers per plant and the percentage of fertility was found by [18].

The Authors [19] also investigated the positive relationship of grain yield with effective tillers / plant. Even the total spikelet per panicle exhibited a positive effect and coefficient of correlation with yield of grain per plant. The Authors [20] reported that total grain contributes positively to grain yield which supports the present finding. Figure 10 showed correlation coefficients between different agronomic traits and grain yield. The elongation ratio (L1 / L0) is a measure of the length of kernel after cooking, which is due to the swelling by water absorption of starch granules [21]. The Author [22] suggested that the elongation ratio be the best quality index as opposed to the elongation index and the proportionate increase. The Authors [23] reported significant association of L / B ratio with kernel elongation. The Authors [24] observed a strong positive association between the elongation and the length of the cooked kernel. Kernel elongation was affected primarily by form and size of the kernel. Consequently, the elongation ratio (L1 / Lo), indicating length elongation, is a better indicator of cooking efficiency than the elongation index indicating both length and width. The greater percentage of milling may not lead to an increased head rice recovery, because it also depends on the size of the grain. The size and shape of the grain, the hardness, the irregular presence or absence of white rice, the quality of the humidity, the precision of harvest, storage, processing and milling conditions have a direct effect upon rice head recovery [25]. In general, rice yields are less high in varieties with long bold grains and white ~~centres~~ Varieties with medium slender, long slender and translucent grains provide high yields of head rice. Even less breaking is experienced by varieties with high protein content. Sun cracking due to alternative drying and wetting of grain due to delays also increases the grain disruption [26]. Grain disruption ~~has also~~ increased. The reverse relation between HRR percent and the grain L / B ratios was reported by the Authors [27, 28].

However, water absorption is essentially the expansion of the volume, subject to the effect of the texture of the kernel [29]. He also stated that the varieties expected to have a significant volume increase are sticky and pasty when cooked. All pasty cooking types were invariably associated with increased water absorption. He concluded that pasty cooking was closely associated with high absorption of water. Hybrids are also more attractive with low water absorption and high-volume expansion.

In order to be commercially successful, the rice variety must have a high total milled rice and a whole grain (HRR) turnout. Various factors like variety, environment and cultural ~~practises~~ may affect the grain's protein content [30]. The amylose content of rice determines the durability and bondage of cooked rice. The amylose content of non-sticky, soft or cooked rice is greater than 25 per cent. Rice with 20–25% amylose produces rice that is soft and relatively sticky [31]. Most of the Bangladeshi citizens prefer high amylose rice.

5. Conclusions

Several 'Boro' genotypes of rice were performed in this research. The variance analysis has shown that the 15 F6 lines for all of the characters ~~analysed~~ display significant variance. The presence of significant improvements in materials means that the performance potentials can be increased. The experiment has shown a wide range of mean values for various characters. G11 was the highest efficient tiller, primary and secondary category, higher grain filling, greater yields of each plant, higher hulling percentage, higher milling outturn, higher HRR, lower absorption of water, protein and high amylose content among these 15 F6 lines. Accumulated information might be useful as potential breeding materials in future 'Boro' rice research in Bangladesh as well as other ~~subtropical~~ countries and G11 (BRRI dhan 28 × BRRI dhan 29 F6 S2 P4 P3) genotypes may be used as potential breeding materials.

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Conflicts of Interest: The authors declare no conflict of interest.

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