

1 **Screening out the early matured ‘Boro Rice’ genotype for Bangladesh condition based on their physi-**
2 **ochemical characteristics and yields**

3
4 **Abstract:** In Bangladesh conditions, the end of the Boro season begins floods and natural calamities and loses
5 more rice in farmer's fields. If we can select early maturity genotypes for the Boro season, we can harvest our
6 rice from the farmer's field before flooding or any other natural calamities. The study was attempted to de-
7 termine the short duration and high yielding rice genotype for Boro season in Bangladesh amongst the 13 Boro
8 rice F6 lines by contrast with two (2) test varieties. Keeping in view this idea, the output of the genotypes
9 studied, the relationship between different morpho-physio-chemical and yield-contributing characteristics
10 between all the genotypes were investigated there under field and laboratory conditions. Among these 15
11 lines, G11 line showed better result in the most of yield contributing parameters. It is therefore concluded that
12 the G11 genotype will be considered an appropriate line for the Boro season in Bangladesh.

13 **Keywords:** Screening, Physio-chemical properties, Yield, Genotype, Rice.
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15 **1. Introduction**

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

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

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

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

37 In view of the above information, boro rice has a vast potential in Bangladesh. The end of the Boro season
38 begins with floods and natural calamities and the loss of more rice in the farmers' fields. If we can select
39 early maturation genotypes for the Boro season, we can harvest our rice from the farmer's field before
40 flooding or any other natural calamity. It is therefore important to develop rice cultivars that are ideally
41 suited to various boro rice-growing situations. Inter-varietal crosses and generation evaluations must be
42 carried out to generate high yielding boro rice cultivars and to select early maturity and high yielding

Comment [U1]: The method was not stated in detail in the abstract section.

Comment [U2]: Introduction should be more focused on the previous works done on this topic

43 materials. The present study was therefore undertaken to identify the appropriate genotype based on their
44 growth parameters, physiochemical and yield-contributing characteristics of selected boro rice genotypes.

45 **2. Materials and Methods**

46 **2.1 Experimental site**

47 The research study was carried at the central farm, Sher-e-Bangla Agricultural University (SAU), Dhaka,
48 Bangladesh, from December 2015 to May 2016. The experimental field was located at 90 ° 22 'E longitude
49 and 23 ° 41' N latitude at an altitude of 8.2 meters above sea level. It was under the Agro-Ecological Zone of
50 Madhupur tract (AEZ No. 28) and its topsoil is clay loam in texture and olive-gray with common fine to
51 medium distinct dark yellowish-brown mottles. The soil pH was 6.10; organic matter (0.84%); total N (0.46
52 %); exchangeable K (0.41meq/100g soil); available P (18.65µg g⁻¹); S (20.92µg g⁻¹); Fe (225µg g⁻¹); Zn,
53 (4.55µg g⁻¹) and Mg (0.81µg g⁻¹).

54 **2.2 Planting materials**

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

60 **2.3 Germination of seed, Seedbed preparation, seedling raising, and transplanting**

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

68 **2.4 Data collection**

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

71 **2.4.1. Morphological**

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

75 **2.4.2. Physiological**

76 **2.4.2.1. Milling and grain appearance**

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

79 **2.4.2.2. Cooking characteristics**

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

82 **2.4.3. Biochemical**

83 Protein (%), Amylose (%)

85 **2.5 Experimental designs and data analysis**

The experiments were designed in a randomized 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)

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

125 **3.1.7 Primary branches per panicle**

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

129 **3.1.8 Secondary branches per panicle**

130 Among the 15 genotypes, the maximum secondary branches per panicle was reported to G11 (40.10), while
131 the minimum secondary branches per panicle was demonstrated in G2 (26.50) which was quite similar to G1
132 (26.76) (Table 3) and their checks were BRRI dhan 29 (32.20) and BRRI dhan 28 (30.23).

133 **3.1.9 Spikelet per panicle**

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

138 **3.1.10 Filled grains per panicle**

139 The maximum filled grains were recorded in G11 (195.96) which was higher than their checks in G14
140 (176.56) and G15 (187.93) respectively (Figure 4). The remainder of the population displayed a different
141 number of grains filled per panicle.

142 **3.1.11 Unfilled grains per panicle**

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

146 **3.1.12 Yield per plant (g)**

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

151 **3.1.13 1000 Seed weight (g)**

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

155 **3.2 Correlations analysis**

156 For indirect selection purposes the correlation analysis of agronomic traits can be used as a selection tool.
157 Correlation studies can easily explain the plant breeder's yield components during the selection process.
158 Table 4 displays most of the variables, including the days to maturity ($R^2 = 0.778$), number of effective tiller
159 ($R^2 = 0.978$), length of panicle ($R^2 = 0.573$), primary branches/panicle ($R^2 = 0.635$), secondary
160 branches/panicle ($R^2 = 0.659$), spikelet per panicle ($R^2 = 0.409$), filled grains per panicle (0.768), yield per
161 plant ($R^2 = 0.968$) and 1000 seed weight (0.709) showed a strong correlation to the key characteristics of the
162 yield. A negative correlation was documented on plant height ($R^2 = -0.311$), a number of the tiller ($R^2 =$
163 -0.328) and unfilled grains per panicle ($R^2 = -0.776$).

164 **3.3 Milling and grain appearance/quality characters of f6 line of boro rice**

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

169 **3.3.1 Kernel length, breadth and their ratio of rough rice**

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

181 **3.3.2 Kernel length, breadth and their ratio of uncooked rice**

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

190 **3.4 Cooking consistency of rice**

191 **3.4.1 Kernel length, breadth, and their ratio of cooked rice**

192 Kernel length, breadth and their ratio (Table 7) of cooked rice varied significantly in different F6 lines. The
193 longest kernel of cooked rice (11.05 mm) was recorded from G1, which was similar to G10 (10.70 mm) and
194 the shortest (7.27 mm) from G6, which was statistically identical with G2 (7.55 mm), G12 (7.54 mm) and
195 BRRI dhan 29 (7.36 mm). Rice grains absorb water during cooking and increase in volume by increasing
196 length or breadth alone or length and breadth both. The highest breadth was observed in G10 (3.74 mm)
197 which was statistically identical with G3 (3.38 mm), G4 (3.31 mm), G5 (3.65 mm), G6 (3.29 mm) and G11
198 (3.40 mm), while the lowest breadth was found from G12 (2.41 mm). The highest kernel length and breadth
199 ratio (3.50) was reported from G1 and the lowest ratio (2.09) from G6, since their checks were 2.85 and 3.04
200 respectively from BRRI dhan 29 and BRRI dhan 28.

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202 **3.4.2 Kernel elongation ratio**

203 Kernel elongation ratio varied significantly for different F6 rice lines (Table 7). Genotype G1 recorded the
204 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 G1 which 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 outturn (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.

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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	GEPB, SAU
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	
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	BRRI, Gazipur
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	
15	(G15)	BRRI dhan 28	

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

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

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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}

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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 4. Correlation coefficients among the agronomic traits using genotypes means

Charact ers	DM	PH	NT	NET	LP	NPBp	NSBP	TSp	NFG p	NUF Gp	Yield /P	TSW
DM	.778 **	-.00 9	-.05 7	-.06 5	-.09 4	-.450 **	-.133	-.09 0	-.02 8	-.044	-.16 4	-.553 **
PH		-.31 1*	-.06 4	-.07 8	-.01 0	-.204	-.105	-.21 8	-.32 6*	.283	-.32 9*	-.310 *
NT			-.32 8*	-.35 6*	-.14 5	.627* *	.237	.315 *	-.01 7	.336*	-.13 4	.359*
NET				.978 **	-.14 2	-.393 **	-.429 **	-.07 6	-.03 1	-.029	.236	-.225
LP					.573 **	-.389 **	-.415 **	-.09 2	-.05 1	-.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
NUFG p										-.776 **	.700 **	-.047
Yield/ P											.968 **	.199
TSW												.709* *

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

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

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Genotype	Kernel length of rough rice	Kernel breadth of rough rice	Kernel Length, breadth ratio of rough rice
G1	8.48 ± 0.04 ^{d-f}	2.61 ± 0.05 ^{b-e}	3.25 ± 0.05 ^d
G2	8.29 ± 0.09 ^{e-g}	2.53 ± 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 ± 0.05 ^{b-d}	3.26 ± 0.05 ^{cd}
G5	8.37 ± 0.12 ^{d-f}	2.59 ± 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 ± 0.11 ^{c-e}	2.36 ± 0.01 ^g	3.69 ± 0.10 ^a
G8	7.91 ± 0.13 ^{gh}	2.56 ± 0.02 ^{c-f}	3.08 ± 0.23 ^e
G9	9.13 ± 0.09 ^{bc}	2.51 ± 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 ± 0.02 ^{b-f}	3.48 ± 0.06 ^{bc}
G13	9.28 ± 0.05 ^b	2.51 ± 0.05 ^{d-g}	3.50 ± 0.16 ^b
G14	8.46 ± 0.04 ^{d-f}	2.42 ± 0.04 ^{fg}	3.50 ± 0.03 ^b
G15	9.04 ± 0.11 ^{bc}	2.47 ± 0.11 ^{e-g}	3.66 ± 0.02 ^{ab}

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

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

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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}

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

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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 ± 0.09 ^{a-c}	2.67 ± 0.07 ^{de}	1.40 ± 0.01 ^{c-e}
G4	9.53 ± 0.01bc	3.31 ± 0.08 ^{a-c}	2.94 ± 0.07 ^{b-d}	1.33 ± 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 ± 0.04 ^{a-c}	2.09 ± 0.17 ^f	1.32 ± 0.01 ^{d-f}
G7	8.75 ± 0.09cd	3.18 ± 0.03 ^{bc}	2.75 ± 0.01 ^{cd}	1.35 ± 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 ± 0.03 ^{b-d}	1.15 ± 0.01 ^g
G10	10.70 ± 0.17a	3.74 ± 0.3 ^a	2.89 ± 0.02 ^{b-d}	1.74 ± 0.01 ^a
G11	9.24 ± 0.93b-d	3.40 ± 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 ± 0.01 ^{e-g}
G14	7.36 ± 0.04f	2.57 ± 0.02 ^d	2.85 ± 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).

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

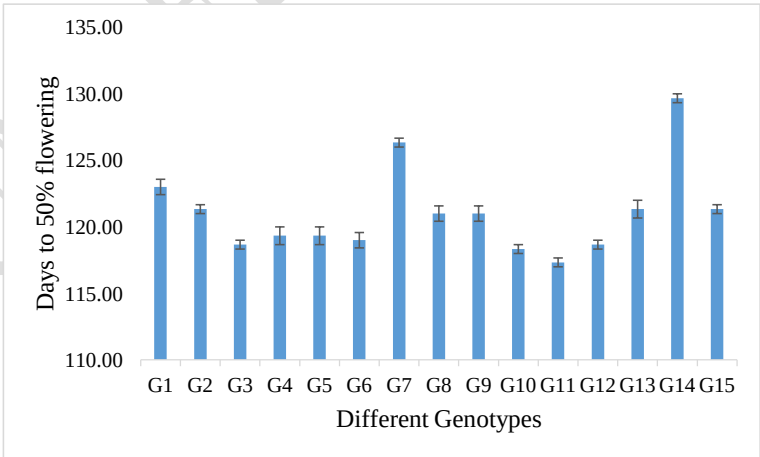
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Genotype	Kernel elongation Index	Volume expansion (%)	Water Absorption (%)	Hulling (%)
G1	1.28 ± 0.02 ^a	40.54 ± 0.57 ^e	315.81 ± 34.02 ^b	70.95 ± 0.25 ^{de}
G2	0.85 ± 0.03 ^{ef}	29.62 ± 0.25 ^h	230.87 ± 3.25 ^{cd}	68.37 ± 0.79 ^f
G3	0.96 ± 0.01 ^{c-e}	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 ^{cf}	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

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

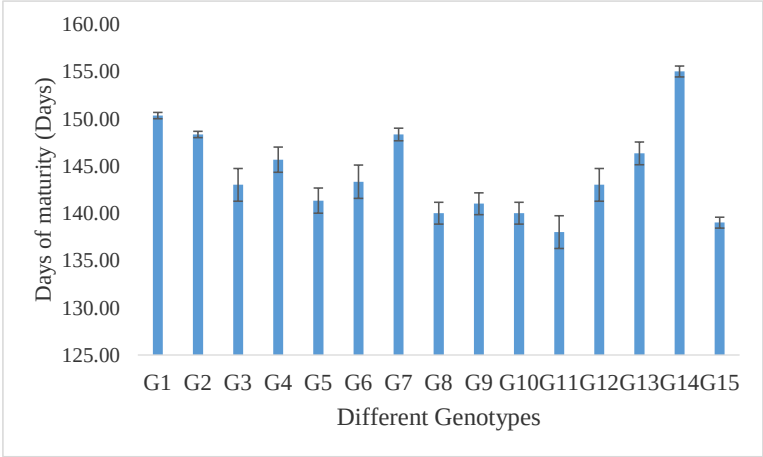
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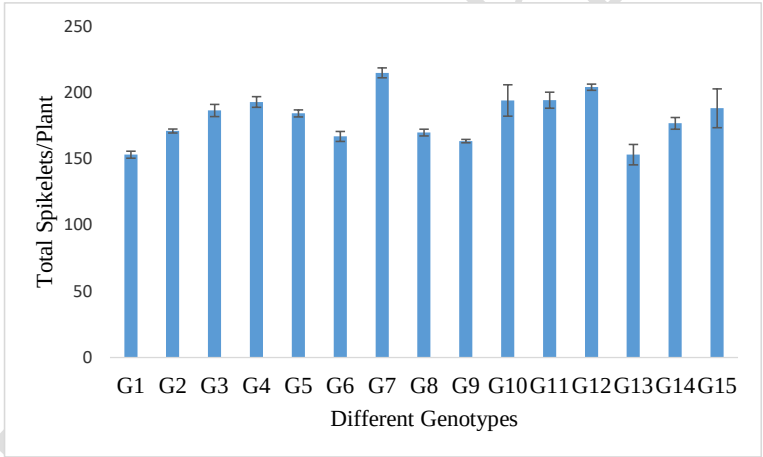
Figure 1. Days of 50% flowering on different F6 lines of Boro rice



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



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

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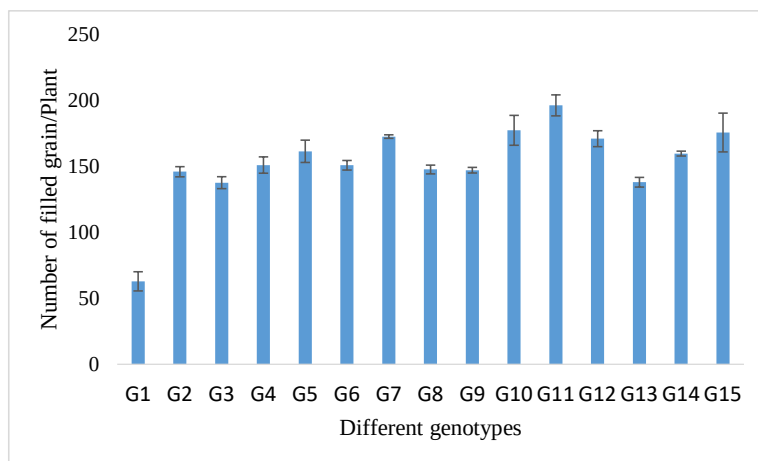


Figure 4. Number of filled grain/Plant on different F6 line of Boro rice

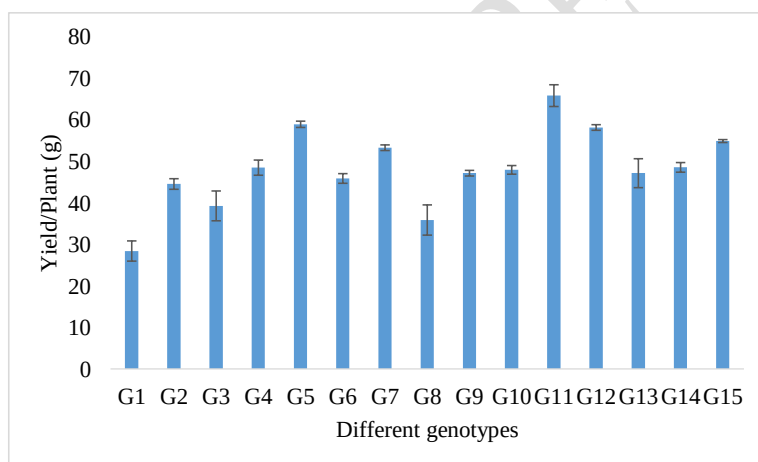


Figure 5. Yield per plant on different F6 line of Boro rice

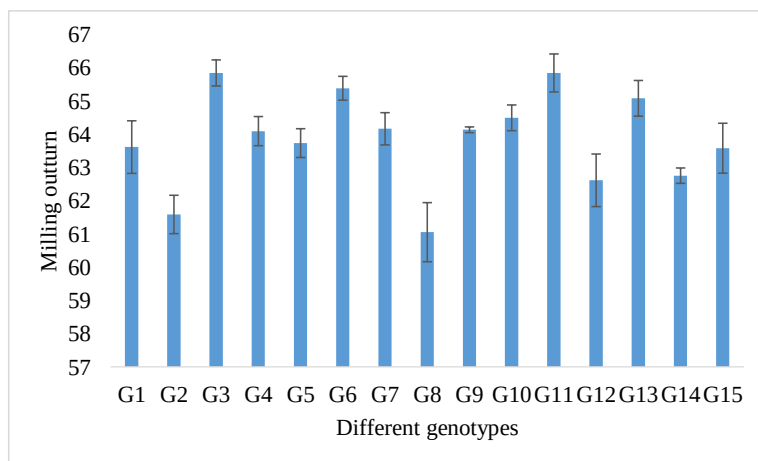


Figure 6. Milling outturn on different F6 lines of Boro rice

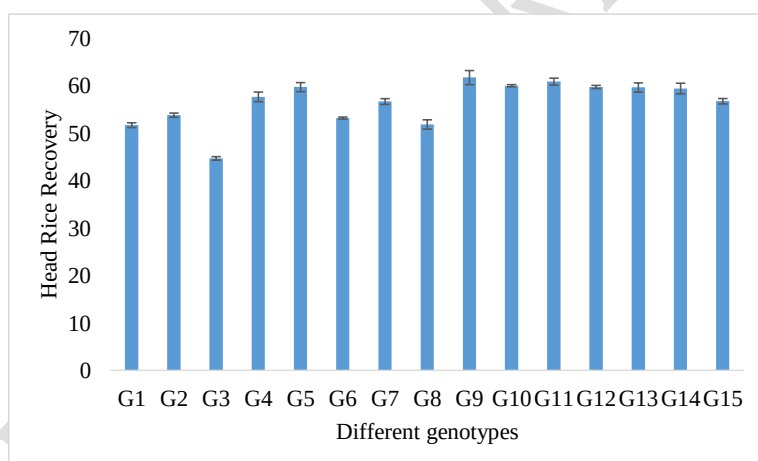


Figure 7. Head Rice Recovery on different F6 lines of Boro rice

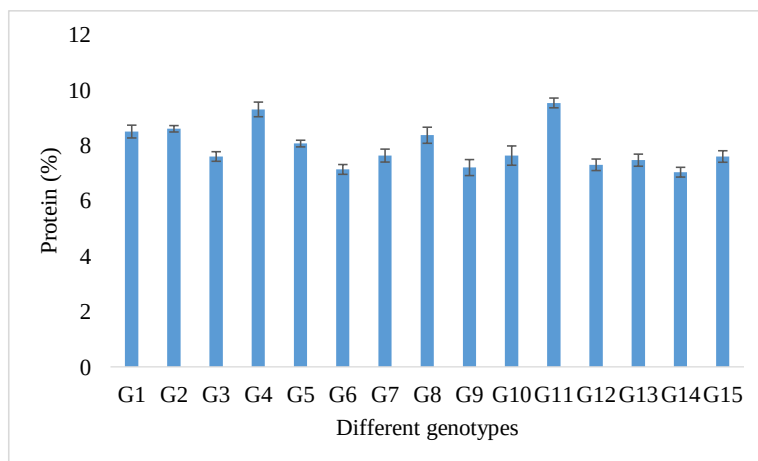


Figure 8. Protein (%) of different F6 lines of Boro rice

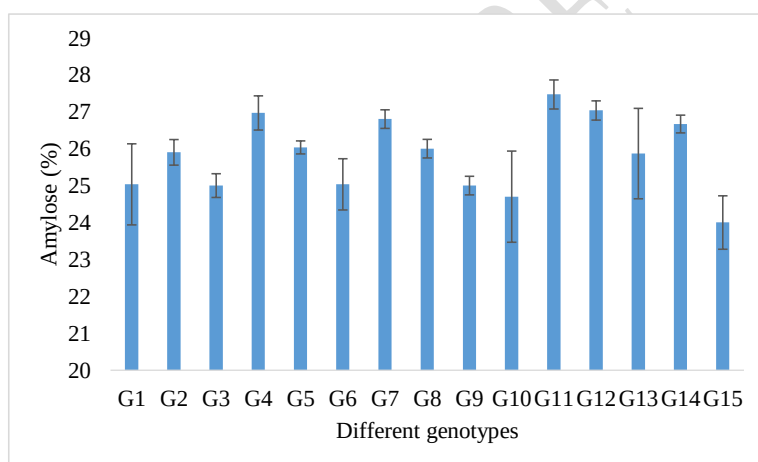


Figure 9. Amylose (%) on different F6 lines of Boro rice

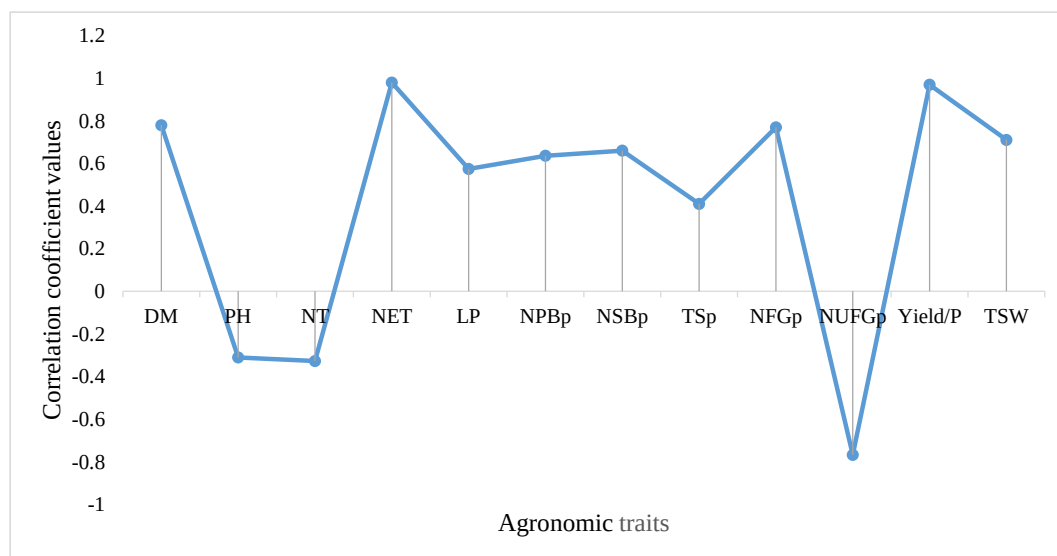


Figure 10. Correlation coefficients between different agronomic traits and grain yield. Indicators: DM= Days to maturity; PH= Plant height; NT= Number of tiller; NET= Number of effective tiller; LP= Length of Panicle; NPBp= Number of primary branches/Panicle; NSBp= Number of secondary branches/Panicle; 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

Comment [U3]: The discussion section does not provide a more profound explanation regarding the data obtained or the relationship between parameters.

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 (L_1 / L_0), 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 centers. 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 is 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 practices 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 analyzed 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 sub-tropical countries and G11 (BRRI dhan 28 × BRRI dhan 29 F6 S2 P4 P3) genotypes may be used as potential breeding materials.

Author Contributions: This work was carried out in collaboration with all the authors. The final version of the manuscript was carefully read and accepted by all authors. E.T. Data curation; Writing-original draft; M.S.R.B. Conceptualization; Investigation; Supervision. Z.K. Data curation; J.U. Formal analysis; Project administration; Writing-review & editing. All authors have read and agreed to the published version of the manuscript.

Comment [U4]: The conclusion section was explained too long

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Data Availability Statement: All data are provided within this paper.

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

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