CHARACTERIZATION AND EVALUATION OF TEN ADVANCED BORO RICE LINES

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CHARACTERIZATION AND EVALUATION OF TEN ADVANCED BORO RICE LINES

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CERTIFICATE

This is to certify that the thesis entitled, **"CHARACTERIZATION AND EVALUATION OF TEN ADVANCED BORO RICE LINES" s**ubmitted to the Department of Genetics and Plant Breeding, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN GENETICS AND PLANT BREEDING,** embodies the result of a piece of Bonafede research work carried out by **Mostarina Tasmin Tinni** Registration No. **18-09029** under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED TO
MY
BELOVED FAMILY

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ABSTRACT

An investigation was carried out under the field conditions to characterize and evaluate study ten F_9 advanced boro rice lines during the period of boro season (2018-2019) at the experimental field of Sher-e-Bangla Agricultural University, Dhaka 1207. The advanced lines were characterized for 31 qualitative and 10 quantitative traits. Variability study was carried out on 12 parameters to select the best lines for further trial. All the lines were characterized and categorized as per the descriptors developed by Biodiversity International, IRRI and WARDA-2007 for DUS test of inbred rice. Among the qualitative character variation was observed in penultimate leaf pubescence, stigma exertion, attitude of the flag leaf blade, panicle curvature, panicle attitude of branches and panicle exertion. Among all the quantitative character time of heading (50% of plants with heads), stem: culm diameter, panicle length, number of effective tillers per plant, time of maturity, thousand grain weight and decorticated grain length showed difference for all the lines which considered for better agronomic performance. The average days to maturity was 137 days and most of the lines showed early maturity (134 days) and lodging resistance. Most of the lines produced average number of effective tillers per plant (13 tillers), panicle length (25.25 cm) and resulted in higher yield per plant. The average thousand grain weight was 22.88 g and average yield was 8.10 ton/ha. In case of variability study plant height, effective tillers per plant, length of panicle, primary branches per panicle, secondary branches per panicle, total spikelet per panicle, filled grains per panicle, thousand seed weight and yield per ha showed significant variations among the lines. Among the ten lines L5 showed the maximum yield per hectare (9.11 t/ha) and the minimum in L10 (7.08 t/ha). The lines L3 (8.66 t/ha) and L5 (9.11 t/ha) produced higher yield and short duration. Thus, the line L5 would be suitable for developing boro rice variety for its short duration and high yield.

Keywords: Boro rice, Advanced line, Characterization, Short duration, High yield**.**

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ABBREVIATION AND ACRONYMS

Short Form		**Full Form**
AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
HRC	=	Horticulture Research Centre
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
N	=	Nitrogen
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Murate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	gram
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
wt	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Co-efficient of Variance

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa*) is the most important staple food for a large part of the world's human population, especially in East and South Asia, the Middle East, Latin America, and the West Indies (Sharif *et al.,* 2014). It provides more than one fifth of the calories consumed worldwide by the human. It is the second leading cereal crop and staple food of half of the world's population. It is grown in at least 114 countries with global production of 645 million tons; share of Asian farmers is about 90% of the total produce (Sharif *et al.,* 2014). Strategies and actions of Bangladeshi agriculture are guided by the goals of 'self-sufficiency' in food grain production with main focus on rice. Over 95% people depend on rice for their daily diets and it engages over 85% of the total agricultural labor force in Bangladesh (GOB, 2017). Agro-based developing country like Bangladesh is striving hard for rapid development of its economy. The economic development of the country is mainly based on agriculture. The contribution of agriculture sector in GDP is 19.29 percent. In the agriculture sector, the crop sub-sector dominates with 14.78 percent in GDP of which rice alone contributes about 53 percent (GOB, 2017). In Bangladesh almost 66% of the labor force depends on agriculture for employment. Bangladesh may be described as a land of rice growers and rice eaters. It is also the staple food of Bangladesh, occupies nearly 90% of the total net cropped area of the country and more than 99% of the people eat rice as their main food @416 gm/person/day (HIES, 2010).

Boro rice is the most important rice among three in terms of area, production and its contribution to the national income and national economic development. (Asaduzzaman *et al.,* 2010). An analysis of area and production of Boro rice during 1980-81 to 2017-18 revealed that both area and production of Boro rice has increased. Area under Boro rice has increased from 11.6 lakh ha in 1980-81 to 46 lakh ha in 2017-18. On the other hand, production of Boro rice increased from 26.3 lakh tons to 1 crore 77.6 lakh tons, while per hectare yield of Boro rice increased from 2.27 ton/ha to 3.86 ton/ha. During this period annual compound rate of growth in area, production and yield of Boro rice was 4.82, 6.49 and 1.68 percent, respectively. In 2017-2018, total production of rice in Bangladesh was 36,391,000 (36.4 million) metric tons (MT), of which boro rice accounted for 53.8 percent; aman rice, 38.6 percent; and aus rice, 7.6 percent (BBS, 2018). Although Boro rice production was profitable in Bangladesh, but there are several problems faced by the farmers to its higher production. The problems were broadly classified as economic, technical, and marketing. Duration of crop ranked first as a problem of Boro rice production. Besides this, high irrigation requirements, low price of output, and shortage of quality seed etc. were ranked as 2nd, 3rd, and 4th major problems of Boro rice production faced by the farmers. Development of short duration Boro variety would be revolutionary.

Morphological characterization of advanced lines is fundamental in order to provide information for the selected lines. Morphological characterization gives the mark of identification which distinguishes one line from other. Characterization of these lines is not only important for utilizing the appropriate attribute-based donors in breeding programs, but is also essential in the present era for protecting the unique rice. However, the utilization of the advanced lines of the rice crop is mostly being used for higher yields and early maturity. Ndour (1998) revealed that, techniques such as plant characterization have been successfully used in identifying elite individual genotypes. It is an indispensable tool for selecting varieties or lines based on agronomical, morphological, genetic or physiological characters. Therefore, in this study, the characterization technique was used to identify the variability that exists among the selected lines. Thus, characterization of these lines would further contribute towards creating genetic database for breeding programs strategies in the future. Genetic diversity is an important tool for a crop improvement program, as it helps in the development of superior recombinants (Manonmani and Fazlullah Khan 2003). Genetic divergence among the genotypes plays an important role in selection of parents having wider variability for different traits (Nayak *et al.*, 2004). The ultimate goal of any plant breeding program is to develop improved genotypes which are better than the existing ones in producing the economic yield. This requires genetic amelioration through maximum utilization of allelic resources to develop ideal genotype. The study of genetic diversity reposes on adapted and appropriate techniques. Techniques such as plant characterization have been successfully used in recent years to help in identifying elite individuals. It is an indispensable tool for selecting varieties or lines based on agronomical, morphological, genetic or physiological characters (Ndour, 1998). Characterization is the technique used to evaluate the phenotypic diversity through agro-morphological traits (Bajracharya *et al.*, 2006). Many studies on genetic diversity using agro-morphological characterization have been conducted and it led to the identification of the phenotypic variability in rice (Barry *et al.*, 2007).

The basic objective of this characterization and evaluation programs is to realize a marked improvement in crop yield through various breeding methods. In order to step up the production potential, it is necessary to launch a dynamic breeding program to develop improved rice varieties suitable for different agro-climatic regions. For planning and execution of a successful breeding program, the most essential pre-requite is the availability of substantial desirable genetic variability for important characters in the germplasm collections of the plant species. The available variability in a population can be partitioned into genetic parameters such as coefficients of variation, heritability and genetic advance to serve as basis for selection of desirable genotypes than existing ones. However, yield is a complex character which is controlled by association of number of components most of which are under polygenic control. Thus, the identification of important components and information about their association with yield and other traits are very useful for developing efficient breeding strategy for evolving high yielding varieties. For development of high yielding Boro rice variety, the crossing between two cultivar (Aus × Boro) having specific desirable characters (short duration and high yield) produces numerous individuals. The superior type individuals are then sorted and cultivated as selected lines. Characterization and variability study of these selected lines is the prerequisite to develop new rice variety. A breeding program was initiated in 2008 to develop short duration and high yielding boro varieties. After a continuous process of selection ten F_9 advanced lines were selected based on their maturity period and yielding ability. The ten F_9 advanced lines obtained through Aus × Boro crosses have been used in the present study. The present study was undertaken to characterize and study of variability of these advanced lines which is the prerequisite to release rice variety. It will pave the ways for selection of high yielding and short duration boro rice from ten advanced lines.

Objectives:

1. To characterize advanced lines of boro rice as per descriptors.

2. To study genetic variability of important quantitative characters among the advanced lines.

3. To select short duration and high yielding boro rice lines for further trial.

CHAPTER II

REVIEW OF LITERATURE

Yield of rice variety is determined by the morphological parameters such as 50% flowering, days to 80% maturity, plant height (cm), tiller per plant, effective tiller per plant, panicle length (cm), primary branches, secondary branches, spikelet per panicle, filled grain of main tiller, unfilled grain of main tiller, yield per plant (g), thousand grain weight (g) and yield (ton/ha.). The extent of existing genetic variability of a crop plant is an index of its genetic dynamism. Plant breeding revolves around selection which can be effectively practiced only in the presence of variability of desired traits. The literature relevant to the present investigation entitled "Characterization and evaluation study of ten advanced boro lines" through morphological traits and variability has been reviewed in this section under following headings;

Morphological characterization

Morphological characters of seeds such as seed coat color, seed shape, seed length, seed width, kernel length, kernel breadth, kernel shape, presence of awn, thousand seed weight etc. and traits of plants such as culm length, time of heading, time of maturity, number of primary branches, number of secondary branches, panicle length, numbers of effective tillers per plant, grains per panicle etc. can invariably be used in characterization of rice genotypes. Genetic studies have revealed that these characters are simply inherited and highly heritable and therefore, could be readily used in distinguishing varieties.

Singh *et al*. (2016) characterized 20 (ten mega varieties and ten landraces) varieties of rice by using 23 morphological traits following Distinctiveness, Uniformity and Stability Test (DUST). Among the 23 DUST characters utilized in the characterization of twenty rice genotypes, six characters viz., the basal leaf sheath color, color of ligule, shape of ligule, auricles, anthocyanin coloration of auricles and anthocyanin coloration of nodes showed no variation and found distinctive among all the cultivars.

The assessment of genetic diversity is an integral part of any successful breeding program. Usually, breeders have been employing morphological markers for genetic diversity estimation and a number of morphological descriptors in various crops are in vogue for characterization purpose (Rana and Bhat, 2004).

2.1. Days to flowering

Venna *et al*. (2002) found that, few crosses showed heterobeltiosis for days to 50% flowering. The correlation between heterosis over better parent and inbreeding depression showed that yield can be improved by direct selection for days to 50% flowering and number of productive tillers per plant.

Iftekharuddaula *et al.* (2001) reported that days to flowering, days to maturity, plant height and spikelet/panicle had positive and higher indirect effect on grain yield through grain/panicle.

Ganesan (2001) said that days to flowering, plant height, number of tiller/plants, and productive tiller/plant had both positive and negative indirect effects on yield.

Sathya *et al.* (1999); studied of eight quantitative traits in rice (*Oryza sativa*). Days to 50% flowering was the principal character responsible for grain yield per plant followed by 1000-grain weight, plant height and harvest index as they had positive and significant association with yield. Vijayakumar *et al.* (1997) found that hybrids out yielded than their parents when their days to 50% flowering were similar or more than their respective restorers. They concluded that superior hybrids could he identified early by comparing their tiller number, plant height and days to 50% flowering with those of their respective restores.

Padmavathi *et al.* (1996) suggested that, days to 50% flowering had high positive direct effects on number of panicles/plant and panicle length on grain yield. 1000-grain weight, dry matter production, spikelet sterility, days to 50% flowering, number of grains/panicle and plant height had positive direct effects on grain yield.

Wang *et al.* (1991) reported that A few crosses showed heterobeltiosis for days to 50% flowering. The correlation between heterosis over better parent and inbreeding depression showed that yield can be improved by direct selection for days to 50% flowering and number of productive tillers per plant.

2.2. Days to maturity

Khush (1999) reported that the optimum growth duration for maximum rice yields in the tropics is thought to be 120 days from seed to seed. Growth duration of about 120 days allows the plant to utilize more soil nitrogen and solar radiation and resulting in high yield. However, for adaptation of various cropping system, varieties with varying growth duration of 100- 130 days are required.

2.3. Plant height (cm)

Bhuiyan *et al.* (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of plant growth and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on plant height at maturity.

Zahid *et al.* (2005) studied 14 genotypes of basmati rice and observed high heritability couple with high genetic advance for plant height and 1000 grain weight. Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and observed that Mukti gave the longest plant compared to the others.

De *et al.* (2002); experimented that plant height ranged from 80.00 to 132.00 cm, whereas panicle length ranged from 22.00 to 29.00 cm. which is responsible for grain yield per plant. Ganesan (2001) reported that plant height, days to flowering, number of tillers/plants, and productive tillers/plant had both positive and negative indirect effects on yield.

Mrityunjay (2001) concluded that hybrids, in general, gave higher values for plant height at harvest, panicle length and number of filled grains per panicle, performed better compared to the others in terms of yield and yield components.

Prasad *et al.* (2001) observed that days to flowering are negatively correlated with plant height. Spanu (2001) conducted that plant height ranged from Oka and Saito (1999) reported that among F1 there were relationships between plant heights; panicle length and number of grains/panicles were higher in the hybrid MH 2005.

Sathya *et al.* (1999) reported that productive tillers per plant, plant height and harvest index are the principal character, which is responsible for grain yield per plant as they had also positive and significant association with yield.

Xu and Li (1998) observed that the maintainer lines were generally shorter than restorer line. He *et al.* (1998) studied that plant height is 102.1 cm and it is directly resistant to rice bacterial leaf blight (*Xanthomonas oryzae*).

Yang (1998) observed that plant height is 95-98 cm while 1000- seed weight is 28 g. The rate of seed set was over 90%. Taste and grain appearance are better than Akihikari. Padmavathi *et al.* (1996) said that high positive direct effects of plant height, number of panicles/plant and panicle length on grain yield. Saravanan and Senthil (1997) reported that high heritability estimates were observed for plant height (99.15%) followed by days to 50% flowering (98.2%) and productive tillers/plant (98.19%).

Marekar and Siddiqui (1996) stated that positive and significant correlations were observed between yield per plot and plant height, length of panicle, days to maturity, 1000-grain weight, length of grain and L/B ratio.

Yu *et al.* (1995) concluded that hybrid where it reaches a height of 90 cm and proved resistant to *Magnaporthe grisea* and *Nilaparvata lugens*. Qiu *et al.* (1994) suggested that enhancing biological yields by increasing plant height would be effective in improving hybrid rice yields.

BINA (1993) evaluated the performance of four rice varieties (IRAATOM 24, BR14, BINA13 and BINA19). It was found that varieties differed significantly in respect of plant height.

Haque *et al.* (1991) reported positive association of plant height with yield per plant but negative association with panicle per plant in modern varieties. BRRI (1991) observed the plant height differed significantly among BR3, BR11, BR14, Pajam and Zagali varieties in the Boro season.

Patnaik *et al.* (1990) found that hybrids with intermediate to tall plant height having non-lodging habit could be developed gave more than 20% grain yield than the standard checks.

Shamsuddin *et al.* (1988) conducted a field trial with nine different rice varieties and observed that plant height differed significantly among the varieties tested.

Futsuhara and Kikuchi (1984) suggested that Dwarfness may be one of the most important physical characters, because it is often accompanied by lodging resistance and there by adapts well to heavy fertilizer application. Plant height is negatively correlated with lodging resistance; positive for plant height in hybrids would not be desirable, particularly with high nitrogen fertilizer. Amirtha devarathinam (1983) reported that Grain yield is negatively correlated with plant height.

2.4. Number of effective tillers per plant

Somnath and Ghosh (2004) reported that the association of yield and yield 9 related traits with the number of effective tillers and had negative association with yield and yield components.

Paramasivam *et al.* (1995); Tahir et al, (2002); reported that Grain yield had positive correlations with number of productive tillers/plant.

Ganesan (2001) reported that plant height, days to flowering, number of tillers/plant, and productive tillers/plant had both positive and negative indirect effects on yield. Ma *et al.* (2001); experimented that ADTRH1 is a rice hybrid. It tillers profusely (12-15 productive tillers per hill) under 20 x 10 cm spacing, with each panicle 27.5-cm long, producing 142 grains. In different trials, ADTRH1 showed 26.9 and 24.5% higher yield over CORH1 and ASD18, respectively, with an average yield of 6.6 t/ha.

Laza *et al.* (2001) concluded that the early vigor of hybrid rice (Oryza sativa) developed in temperate areas has been mainly attributed to its higher tillering rate. However, the tillering rate of hybrids was significantly lower than or equal to that of conventional varieties.

Nuruzzaman *et al.* (2000) concluded that tiller number varied widely among the varieties and the number of tillers per plant at the maximum tiller number stage ranged between 14.3, 39.5, and 12.2, 34.6. Nehru *et al.* (2000) observed that the number of productive tillers directly correlated with yield and thus improved yields.

Padmavathi *et al.* (1996) and Jiang *et al.* (2000) observed the importance of number of tillers/plant which influencing yield. Nehru *et al.* (2000) suggested that increased yield might be due to increased numbers of tillers and spikelets fertility percentage and test weight.

Thakur *et al.* (1999) studied genetic variability and correlations among grain yield and its attributing traits, in an F2 population in hybrid rice. Correlation studies suggested that tillers per plant, had a positive association with grain yield, plant height, panicle weight, biological yield and harvest index.

Sathya *et al.* (1999) studied of eight quantitative traits in rice (Oryza sativa), productive tillers per plant was the principal character responsible for grain yield per plant followed by 100-grain weight, days to 50% flowering, plant height and harvest index as they had positive and significant association with yield. Ashvani *et al.* (1997) studied twenty-two genotypically diverse strains of hybrid rice were to correlate yield contributing characters. Number of effective tillers/plant showed significant and positive correlation at genotypic and phenotypic levels with, grain yield/panicle, 1000-grain weight and total biological yield/plant. Saravanan and

Senthil (1997) studied that information on heritability. High heritability estimates were observed for productive tillers/plant (98.19%), plant height (99.15%) followed by days to 50% flowering (98.2%).

Mishra *et al.* (1996) concluded that number of tillers per hill and number of grains per panicle exhibited positively high significant correlation with yield. Reddy and Kumar (1996) reported that Productive tillers/hill showed significant positive correlations with grain yield.

Ganapathy *et al.* (1994) studied that the number of productive tillers per hill, panicle length and grains/panicle had a significant and positive association with grain yield.

Miller *et al.* (1991) reported that Rice tillering is a major determinant for panicle production. Effective tillers/plant, number of grains/panicle and grain weight as the major contributing characters for grain yield were reported by Ghosh and Hossain (1988).

Ghose and Ghatge (1960) stated that tiller number, panicle length contributed to yield.

2.5. Panicle length (cm)

Laza *et al.* (2004) study was measured with yield-related traits, panicle size had the most consistent and closest positive correlation with grain yield. Guimara (2002) indicate that the plants with cooperatively large panicles tend to have a high number of filled gains. However, most of the cases a positive correlation was observed between number of panicle/plant and panicle length.

Sharma (2002) worked with fine grain rice and reported that there had been significant variation in panicle length. Tahir *et al.* (2002) studied genetic variability for various traits. He found that these traits are under the genetic control and could be use in the selection of a desirable trait.

Ganesan (2001) conducted that panicle length (0.167) had the highest significant positive direct effect on yield/plant followed by number of tillers/plant (0.688), panicle exertion (0.172), and plant height (0.149). Nehru *et al.* (2000) showed that values for test weight and yield differed significantly for hybrids (21-24 g) and varieties (19-23 g). No differences in panicle length were noted between the two groups.

Marekar and Siddiqui (1996) concluded that positive and significant correlations were observed between yield per plot and plant height, length of panicle, days to maturity, 1000-grain weight, length of grain and L/B ratio. Padmavathi *et al.* (1996) concluded that number of tillers/plant, number of panicles/plant, panicle length and 1000-grain weight was positively associated with grain yield. Sawant *et al.* (1995) concluded that panicle length was negatively correlated with flowering time and positively correlated with tiller height.

Ganapathy *et al.* (1994) reported that panicle length, the number of productive tillers per hill, and grains/panicle had a significant and positive association with grain yield. Ramalingam *et al.* (1994) observed that varieties with long panicles, a greater number of filled grains and more primary rachis would be suitable for selection because these characters have high positive association with grain yield and are correlated among themselves.

Wang *et al.* (1991) reported that the length of panicle varied from 26.30 cm to 27.50 cm among the jaixmica hybrids.

2.6. Filled grain per panicle

Ismachin and Sobrizal (2006) reported that in hybrids, yield was primarily influenced by effective tillers per plant and fertile grains per panicle, whereas in parents it was panicle length, maturity and effective tillers per plant.

Yuan *et al.* (2005) the variation in fertile grain percentage/panicle in indica was greater than that in japonica Parvez *et al.* (2003) reported that yield advantage for the hybrid rice is mainly due the proportion of filled grains per panicle, heavier grain weight (35%) and increased values than the control (28%). Chaudhary and Motiramani (2003) filled grain yield per panicle showed significant positive correlation with effective tillers per plant, spikelets density and biological yield per plant.

Tahir *et al.* (2002) reported highly significant variation for the grain per panicle for different genotypes. Other factors i.e. soil fertility, plant nutrients, translocation and weather condition might also responsible. Liu and Yuan (2002) studied the relationships between high yielding potential and yielding traits. Filled grains per panicle was positively correlated with biomass, harvest index and grain weight per plant. Mrityunjay (2001) studied the performance of 4 rice hybrids and 4 high yielding rice cultivars and reported that hybrids, in general, gave higher values for number of filled grains per panicle.

Ganesan (2001) conducted that an experiment of 48 rice hybrids. Filled grains/panicle (0.895) had the highest significant positive direct effect on yield/plant followed by number of tillers/plant (0.688, panicle length (0.167) and plant height (0.149). Rajesh and Singh (2000) reported that in hybrids, yield was primarily influenced by effective tillers per plant and fertile grains per panicle, whereas in parents it was panicle length, maturity and effective tillers per plant. Number of effective tillers per plant and fertile grains per panicle remained constant and common in explaining heterosis for yield of most of the hybrids.

Cristo *et al.* (2000) observed the highest correlation between full grains per panicle, final height and panicle length and yield. Oka and Saito (1999) experimented that among F1 hybrids from crosses of rice cv. Sasanishiki with other cultivars there were relationships with parental values for grain number/panicle, panicle length, and panicle emergence date.

Ramana *et al.* (1998) observed that hybrids produced more panicles m-2 and filled grains per panicle than conventional cultivars. Dhananjaya *et al.* (1998) evaluated some 121 elite homozygous rice genotypes. Most variation was observed for filled grain/panicle, number of fertile spikelets and grain yield/plant. Grain yield was positively correlated with number of filled grain/panicle, harvest index, panicle density, 1000-grain weight, number of productive tillers and plant height.

Mani *et al.* (1997) investigate the extent of genetic variation and interrelationship among them. A wide range of variation was recorded for all the traits. A high estimate of heritability coupled with high genetic advance for number of filled grains/panicle suggested the predominance of additive gene action for this character. Liu *et al.* (1997) evaluated 24 indica x japonica hybrids where, filled grain/panicle (FSP) spikelets/panicle (SP), and 1000-grain weight was positively correlated with GWP. Filled grain/panicle (FSP) had the highest effect on GWP.

Mishra *et al.* (1996) concluded that phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) estimates were higher no. of tillers per hill and number of grains per panicle exhibited positively high significant correlation with yield. Padmavathi *et al.* (1996) concluded that number of filled grains/panicle, plant height 1000-grain weight, dry matter production, spikelets sterility, days to 50% flowering had positive direct effects on grain yield.

Lin (1995) studied the relationship among filled grains/panicle, grain size, yield components and quality of grains. The percentage of filled grains/panicle was the most important factor affecting grain yield.

Ramalingam *et al.* (1994) examined the varieties with long panicles, a greater number of filled grains/panicle and more primary rachis would be suitable for selection because these characters have high positive association with grain yield.

Yang and Song (1994) observed that heterosis was highest for number of effective panicles (59.06%) and high for total filled grain number/main panicle (42.44%). Number of effective grains/ panicles was correlated with 100-grain weight and 10-grain length. Ganapathy *et al.* (1994); said that the number of filled grains/panicle, productive tillers per hill, panicle length had a significant and positive association with grain yield.

Mahajan (1993) indicated that filled grains/panicle, grain yield/plant was positively and significantly correlated with straw yield/plant. Geetha (1993) indicated that number of ear-bearing tillers, filled grain/per panicle, percentage filled grain, and test weight, straw yield and harvest index were all correlated positively with grain yield. Gravois and Helms (1992) reported the importance of number of filled grains per panicle in determination of rice yield.

Patnaik *et al.* (1990) reported that the heterosis for grain yield was due to the significant heterosis for the number of spikelet/panicle, test weight and total dry matter accumulation.

2.7. Total grains per panicle

Sarkar *et al.* (2005) studied the number of grains/panicle was negatively associated with number of panicle. Yuan *et al.* (2005) studied the variation in the yield components of 75 high quality rice cultivars. Among the yield components, the greatest variation was recorded for number of grains per panicle in indica rice, and number of panicles in japonica rice.

Ma *et al.* (2001) examined under 20 x 10 cm spacing, producing 142 grains/panicle, and with more than 90% spikelet fertility. The hybrid recorded the highest grain yield 11.4 t/ha. Chen-Liang *et al.* (2000) showed that the cross between Peiai 64s and the new plant type lines had strong heterosis for filled grains per plant, number of spikes per plant and grain weight per plant, but heterosis for spike fertility was low.

Oka and Saito (1999) experimented that among F1 hybrids crosses with rice cv. Sasanishiki. Plant height, panicle length and number of grains/panicle were higher in the hybrid than in Sasanishiki, but the 1000-grain weight was lower.

Wey and Traore (1998) analyzed of yield components. The most important components were the number of panicles per plant and the number of grains per panicle.

Dhananjaya *et al.* (1998) most variation was observed for productive tillers/plant, number of fertile spikelets and total grain yield/plant. Grain yield was positively correlated with harvest index, panicle density; number of fertile spikelets, 1000-grain weight, number of grains and plant height.

Mishra *et al.* (1996) concluded that phenotypic coefficient of variation and genotypic coefficient of variation estimates were high for grains per panicle. Number of tillers per hill and total number of grains per panicle exhibited positively high significant correlation with yield.

Xiao *et al.* (1996) indicated that heterosis in F1 hybrids for spikelets/panicle showed a positive and significant correlation with genetic distance in indica × indica but not in indica × japonica crosses.

Lin (1995) studied the relationship among the grain size, yield components and quality. The percentage of filled grains was the most important factor affecting grain yield. Yang and Song (1994) reported that in a hybrid from crosses heterosis was highest for number of effective panicles (59.06%) and high for total grain /main panicle (42.44%).

Ganapathy *et al.* (1994) concluded that the number of productive tillers per hill, panicle length and grains/panicle had a significant and positive association with grain yield. Positive association between grain number per panicle and grain yield has been reported by number of workers (Chauhan *et al.*, 1986; Janagle *et al.*, 1987; Kalaimani and Kadambavanaundaram, 1988).

Choi (1985) reported that grain yield was positively correlated with spikelet numbers/panicle.

2.8. 1000-grain weight (g)

Sarkar *et al.* (2005); said that the highest heritability value was registered for 1000-grain weight, followed by brown kernel length and grain length. Tahir *et al.* (2002) reported highly significant variation among different traits and observe that these traits are under the control of genotypic difference among the genotypes. Other factors like: adaptability, temperature, soil fertility, transplantation season and time might also be responsible for thousand seed weight.

Ma *et al.* (2001); experimented that ADTRH1 is a rice hybrid. 1000-grain weight is 23.8 g. In different trials, ADTRH1 showed 26.9 and 24.5% higher yield over CORH1 and ASD18.

Iftekharuddaula *et al.* (2001) reported that genotypic correlation co-efficient were higher than the corresponding phenotypic correlation coefficient in most of the traits. Days to flowering, days to maturity, grains per panicle, 1000-grain weight and harvest index showed significant positive correlations with grain yield. Sathya *et al.* (1999) reported that 1000-grain weight, days to 50% flowering, plant height and harvest index as they had positive and significant association with yield.

Sitaramaiah *et al.* (1998) showed negative and significant standard heterosis for 1000 grain weight because the check had bold grains. Mishra and Pandey (1998) evaluated standard heterosis for seed yield in the range of 44.7 to 230.9% and 42.4 to 81.4%, respectively. Heterosis for seed yield was due to the positive and significant heterosis for components like panicle length and 1000 grain weight.

Li and Yuan (1998) reported that parental genotype divergence had a relatively low impact on heterosis for panicle number and 1000 grain weight. Yang (1998) studied that Chao Chan-l hybrid rice was 1000-seed weight is 28 g. which is directly related with yield.

Ashvani *et al.* (1997) stated that 1000 grain weight and total biological yield/plant may be considered for further improvement of rice. Huang *et al.* (1997) reported negative association of 1000 grain weight and yield per plant in traditional varieties.

Padmavathi *et al.* (1996) concluded that number of tillers/plant, number of panicles/plant, panicle length and 1000-grain weight was positively associated with grain yield. Marekar and Siddiqui (1996) observed that positive and significant correlations between yield per plot and plant height, length of panicle, days to maturity, 1000-grain weight, length of grain and L/B ratio. Kumar *et al.* (1994) stated that grain weight was highly correlated to grain size, which is product of grain length and width that are inherited independently and this independent inheritance led to variation in F1 grain weights.

Saha Ray *et al.* (1993) reported that Plant height, panicle per plant, grain per panicle and 1000 grain weight increase the yield in modern varieties Haque *et al.* (1991) reported negative association of 1000 grain weight and yield per plant in traditional varieties. Kim and Rutger (1988) observed positive yield predominantly in 1000- grain weight and no. of spikelets per plant. They also observed high correlation between 1000-grain weight and grain yield.

Kaneda (1985) evaluated standard heterosis for seed yield in the range of 44.7 to 230.9% and 42.4 to 81.4%, respectively. Heterosis for grain yield was due to the positive and significant heterosis for components like panicle length and 1000 grain weight.

2.9. Grain yield/plant

Chaudhary and Motiramani (2003) reported that grain yield per plant showed significant positive correlation with effective tillers per plant, spikelets density and biological yield per plant. Almost all characters exhibited high heritability coupled with high genetic advance, except harvest index.

Pruneddu and Spanu (2001) data are tabulated on grains per plant, days from sowing to maturity, grain yield, and plant height, number of fertile stems per m2, 1000-grain weight and yield percentages. Yields were generally lower mainly due to unfavorably high temperatures. Ganesan (2001) concluded that grains/plant had the least significant positive direct effect on number of tillers/plant (0.688), panicle exertion (0.172), panicle length (0.167) and plant height (0.149). Yield improvement of rice grain yield is the main target of breeding program to develop rice varieties for diverse ecosystems. In addition, grain yield also related with other characters such as plant type, growth duration, and yield components (Mao, 2001).

Thakur *et al.* (1999) stated that high heritability coupled with high genetic advance were estimated for biological yield, panicle-weight, branches per panicle and grains per plant, and indicated the major contribution of additive gene action for expression of these characters.

Pushpa *et al.* (1999) evaluated fifty genotypes of upland rice for 10 quantitative traits. The genotypic coefficient of variation was highest for grain yield/plant and also high for spikelets/panicle and grain yield/panicle. Chauhan *et al.* (1999) grain yield was positively associated with dry matter at 50% flowering, biological yield and harvest index. Leaf area index, dry matter accumulation of 50% flowering, biological yield and harvest index seemed to be important in improving grain yield.

Oka and Saito (1999) experimented that among F1 hybrids from crosses of rice cv. Sasanishiki. The hybrid MH 2005 gave a yield of 6.09 t/ha compared with 4.36 t/ha from cv. Hitomebore. Plant height, panicle length and number of grains/plant were higher in the hybrid than in Hitomebore, but the 1000-grain weight was lower.

Dhananjaya *et al.* (1998) evaluated that grain yield was positively correlated with harvest index, panicle density, number of fertile spikelets, 1000-grain weight, number of productive tillers and plant height. Ashvani *et al.* (1997) observed that grain yield/plant showed significant and positive correlation at genotypic and phenotypic levels with number of effective tillers/plant, grain yield/panicle, 1000 grain weight and total biological yield/plant.

Paul and Kand (1997) said that yield was negatively correlated with false grains/panicle days to maturity, plant height and filled grains/panicle. Ganapathy *et al.* (1994) concluded that the number of productive tillers per hill, panicle length and grains/panicle had a significant and positive association with grain yield.

Geetha *et al.* (1994) studied those six hybrids for grain characters. ADRH4 was the highest yielding (19.7 g/plant). The increased yield in this hybrid was due to a higher number of grains per plant. Correlation analysis revealed that only grains per plant had a strong positive association with grain yield.

Mahajan *et al.* (1993) indicated that grain yield/plant was positively and significantly correlated with straw yield/plant and filled grains/panicle. Bai *et al.* (1992) reported that grain yield per plant positively correlated with numbers of productive tillers and number of grains per/panicle.

CHAPTER III

MATERIALS AND METHODS

In this chapter the details of the different experimental materials and methodologies followed during the course of research are presented. A brief description of the experimental site and duration, experimental treatment, materials and technologies used for the study, the procedure of data collection, recording and statistical analysis are explained under the following headings:

3.1 Experimental Site

The experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during November 2018 to April 2019. The location of the site was situated at 23°41' N latitude and 90°22' E longitude. Geographically the experimental field is located at 8.4 meter above the mean sea level. The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.2 Climate and Soil

The experimental site was medium high land belonging to old Madhupur tract (AEZ-28). The soil of the experimental plot was clay loam in texture having pH around 6.5 and organic carbon content is 0.84%. The experiment area was above flood level and having available irrigation and drainage system and has been presented in Appendix II. The experimental site was under the subtropical climate. It is characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October. Details of the metrological data of air temperature, relative humidity, rainfall and sunshine hour at the time of experiment was collected from the weather station of Bangladesh, Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix III.

3.3 Planting Materials (Lines)

Ten selected advance lines were used as experimental materials in the study. Descriptions of the lines are given in Table l.

Table 1. List of materials used in the experiment

Lines	Pedigree	Source
L1	BRRI dhan 29 × BRRI dhan 36 $S_5P_2P_4S_6$	Germplasm center of Sher-e-Bangla Agricultural University (SAU)
L2	BRRI dhan 29 × BRRI dhan 36 $S_2P_2P_4S_6$	
L3	BRRI dhan 21 × BRRI dhan 29 $S_2P_1S_1$	
L4	BRRI dhan 29 × BRRI dhan 36 $S_5P_2P_4S_3$	
L5	BRRI dhan 21 × BRRI dhan 29 $S_6P_1P_1S_2$	
L6	BRRI dhan 26 × BRRI dhan 28 $S_1P_9P_4S_1$	
L7	BRRI dhan 28 × BRRI dhan 29 $S_2P_4P_3S_2$	
L8	BRRI dhan 28 × BRRI dhan 29 $S_2P_4P_3S_3$	
L9	BRRI dhan 21 × BRRI dhan 29 $S_6P_1P_1S_1$	
L10	BRRI dhan 29 × BRRI dhan 36 $S_5P_2P_4S_5$	

L=Lines

Plate 1. Seed soaking for germination

Plate 2. Seed sowing in seedbed

Plate 3. Transplanting in main field

Plate 4. Field view of the experimental plot

3.4 Design and Layout

The experiment was laid out in randomized complete block design (RCBD) with three replications. The field was divided into three blocks; the blocks were sub-divided into 10 plots where lines were randomly assigned. The experimental field size was 27 m × 14 m where 1m border was maintained surrounding the field and every block. The experimental field was designed such a way where row to row distance was 25 cm and plant to plant distance was 25 cm. The 10 genotypes were distributed to each plot within each block randomly.

3.5 Collection of Seed

The seeds of ten advance lines of boro rice (from F_9 generation) were collected from germplasm center of Sher-e-Bangla Agricultural University (SAU).

3.6 Germination of Seed

Seeds of all collected boro lines soaked separately for 48 hours in clothes bag. Soaked seeds were picked out from water and wrapped with straw and gunny bag to increase the temperature for facilitating germination. After 72 hours seeds were sprouted properly.

3.7 Seedbed Preparation and Seedling Raising

The seed bed was prepared well by puddling the wetland. Sprouted seeds were sown separately in the previously wet seedbed on 02 December, 2018. Proper care was taken so that there was no infestation of pest and diseases and no damage by birds.

3.8 Preparation of Main Field

The land was prepared thoroughly by 3-4 ploughing followed by laddering to attain a good puddle. Weeds and stubbles were removed and the land was finally prepared by the addition of basal dose of fertilizers.

3.9 Application of Fertilizers

The fertilizers N, P, K, S in the form of urea, TSP, MOP, respectively were applied. The entire amount of TSP, MOP, Gypsum, Zinc Sulphate and Cowdung were applied during final land preparation. Urea was applied in two equal installments during ploughing and vegetative stage. The dose and method of application of fertilizer are sown in Table 2.

Table 2. Dose and method of application of fertilizers in rice field

Fertilizers	Dose (kg/ha)	Application (required)	
		1st installment	2nd installment
Urea	300	6 kg	6 kg
TSP	100	4 kg	-
MP	120	5 kg	-
Gypsum	110	4.5 kg	-
Zinc Sulphate	10-12	450g	-

3.10 Transplanting of Seedling

Healthy seedlings of 32 days old were transplanted on 03 January 2019 in separate strip of experimental field. Water level was maintained properly after transplanting.

3.11 Intercultural Operation and After Care

After establishment of seedlings, various intercultural operations were done for better growth and development of the rice seedlings.

3.11.1. Irrigation and Drainage

Flood irrigation was given to maintain a constant level of standing water up to 6 cm in the early stages to enhance tillering, proper growth and development of the seedlings and 10-12 cm in the later stage to discourage late tillering. The field was finally dried out 15 days before harvesting.

3.11.2. Gap Filling

First gap filling was done for all of the plots at 10 days after transplanting (DAT).

3.11.3. Weeding

Weddings was done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at tillering stage and at panicle initiation stage by mechanical means.

3.11.4. Top Dressing

The remaining doses of urea were top dressed in 2 equal installments. The fertilizers were applied on both sides of seedlings rows with the soil.

3.11.5. Plant Protection Measure

Proper control measures were taken against rice stem borer during tillering and heading stage of rice. Furadan 5 G @ 04 g per m^2 was applied at active tillering stage and panicle initiation stage of rice for controlling rice yellow stem borer. Cupravit 80 WP @ 2.5 gm per liter water was applied against bacterial leaf blight of rice.

3.11.6. Harvesting, Threshing and Cleaning

The rice was harvested depending upon the maturity of plant and harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for threshing and also cleaning of rice seed. Fresh weight of grain was recorded. The grains were cleaned and finally the weight was adjusted to 14% moisture content.

3.12 Methods of Recording of Observations

To study the stable diagnostic characteristics data and morphological characters were collected from ten randomly selected hills from each replicated plot. The plants were selected from middle of each plot to avoid border effect and portion of the plot. The mean was estimated. Thirty-one qualitative and ten quantitative traits were recorded using the descriptors developed by Bioversity International, IRRI and WARDA-2007. The descriptors are shown in the Appendix VI & VII. The observations for characterization were recorded under field condition as follows.

3.12.1 Qualitative Traits Evaluation

The experimental plots were visited every day and required data were collected as per schedule. An appropriate data record book was used for keeping records of data related to identification of the genotypes. Rice descriptors developed by The

Bioversity International, IRRI and WARDA-2007 (Appendix VI & VII) were used for data collection and recording. The photographs of specific trait considered to be helpful for identification of the genotypes were taken from the experimental field at appropriate times for different traits to compare the distinctness among the rice genotypes. Photographs and data related to distinctness in morphological traits were taken on each of the ten boro lines.

3.12.1.1 Leaf Sheath: Anthocyanin color

Data were collected at early vegetative stage on leaf sheath anthocyanin color and the boro lines were classified into two groups with codes according to guided descriptors as follows.

Absent-1 and Present-9.

3.12.1.2 Leaf Color

Observations with respect to green coloration of leaf at late vegetative stage the boro lines were classified into seven groups with codes according to guided descriptors as follows.

Pale green-1, Green-2,

Dark green-3, Purple tip-4,

Purple margins-5,

Purple blotch-6 and Purple-7.

3.12.1.3 Penultimate Leaf Pubescence

It was assessed both visually and by touch, rubbing fingers over the leaf surface from the tip to downwards at late vegetative stage and the observed lines were categorized into three groups as per descriptors by following way.

Absent or very weak-1,

Weak or only on the margins-3,

Medium hairs on the medium portion of the leaf-5, Strong hairs on the leaf blade-7 and Very strong-9.

3.12.1.4 Penultimate Leaf: Anthocyanin coloration of auricles and collar

Data were collected at late vegetative stage on penultimate leaf anthocyanin coloration of auricles and collar and the observed lines were classified into two groups with codes according to guided descriptors as follows.

Absent-1 and Present-9.

3.12.1.5 Penultimate Leaf: Ligule

Data were collected at late vegetative stage on penultimate leaf ligule and the observed lines were classified into two groups with codes according to guided descriptors as follows.

Absent-1 and Present-9.

3.12.1.6 Penultimate Leaf: Shape of the ligule

Shape of the penultimate leaf ligule was observed and the lines were categorized as following which are also shown hypothetically in Figure 1.

Absent-0, Truncate-1,

Acute to acuminate-2 and

Split or two-cleft-3.

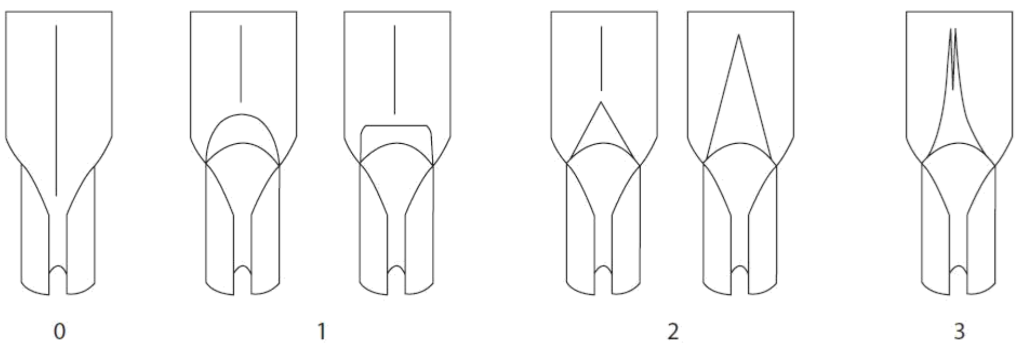


Figure 1. Ligule shape.

3.12.1.7 Flag Leaf: Attitude of the blade

Attitude of the blade of flag leaf is angle of attachment between the flag leaf blade and the main panicle axis. It was just visually observed at anthesis period and classified into following four groups.

Erect (<30˚)-1,

Intermediate or Semi-erect (30˚-45˚)-3,

Horizontal (46˚-90˚)-5 and

Reflexed or descending (>90˚)-7

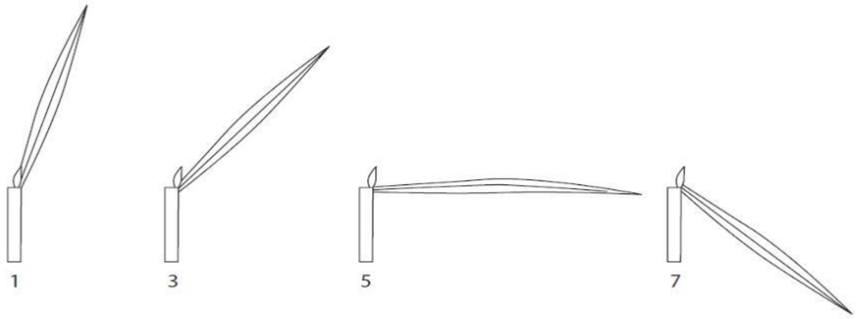


Figure 2. Flag leaf attitude

3.12.1.8 Male Sterility

It was observed at anthesis period of rice and grouped as descriptors.

Absent-1,

CMS-3, TGMS-5,

PGMS-7 and P (T) GMS-9.

3.12.1.9 Microscopic Observation of Pollen with I2-KI solution

It was observed at anthesis period of rice using microscope and the observed lines were classified into eight groups with codes according to guided descriptors as follows.

Completely sterile with TA pollen-1,

Completely sterile with 80% TA pollen-2,

Completely sterile with 50% TA pollen-3,

Sterile (91-99%)-4, Partial sterile (31-70%)-5,

Partial fertile (31-70%)-6, Fertile (21-30%)-7 and Fully fertile (0-20%)-8.

3.12.1.10 Lemma and Palea: Anthocyanin coloration

Data were collected at pre-ripening stage on grain anthocyanin coloration of lemma and palea and the observed lines were classified into five groups with codes according to guided descriptors as follows.

Absent or very weak-1,

Weak-3, Medium-5,

Strong-7 and Very strong-9.

3.12.1.11 Lemma: Anthocyanin coloration of area below apex

Data were collected at pre-ripening stage on grain anthocyanin coloration of lemma and the observed lines were classified into five groups with codes according to guided descriptors as follows.

Absent or very weak-1, Weak-3, Medium-5,

Strong-7 and Very strong-9.

3.12.1.12 Lemma: Anthocyanin coloration of apex

Data were collected at pre-ripening stage on grain anthocyanin coloration of lemma and the observed lines were classified into five groups with codes according to guided descriptors as follows.

Absent or very weak-1, Weak-3, Medium-5,

Strong-7 and Very strong-9.

3.12.1.13 Color of Stigma

Data were observed at anthesis period using a hand lens or magnifying glass and the observed lines were classified into five groups with codes according to guided descriptors as follows.

White -1, Light green-2, Yellow-3,

Light purple-4 and Purple-5.

3.12.1.14 Stigma Exertion

Data were observed at anthesis period using a hand lens or magnifying glass and the observed lines were classified into five groups with codes according to guided descriptors as follows.

No or a few (>5%)-1, Low (5-20%)-3,

Medium (21-40%)-5, High (41-60%)-7 and

Very high (>61%)-9.

3.12.1.15 Stem: Anthocyanin coloration of nodes

Data were collected after flowering to near maturity stage on stem anthocyanin coloration of nodes and the observed lines were classified into two groups with codes according to guided descriptors as follows.

Absent-1 and Present-9.

3.12.1.16 Stem: Intensity of anthocyanin coloration of nodes

Data were collected after flowering to near maturity stage on stem anthocyanin coloration of nodes and the observed lines were classified into four groups with codes according to guided descriptors as follows.

Weak-3,

Medium-5,

Strong-7 and Very strong-9.

3.12.1.17 Stem: Anthocyanin coloration of internodes

Data were collected at near coloration maturity stage on stem anthocyanin coloration of internodes and the observed lines were classified into five groups with codes according to guided descriptors as follows.

Absent or very weak-1,

Weak-3, Medium-5,

Strong-7 and Very strong-9.

3.12.1.18 Panicle Curvature of Main Axis (i.e., recurrent main axis)

Data were collected at near maturity stage and the observed lines were classified into four groups with codes according to guided descriptors as follows.

Absent or very weak (upright)-1,

Weak (semi-upright)-3, Medium (slightly drooping)-5 and

Strong (strongly dropping)-7.

3.12.1.19 Spikelet: Pubescence of lemma and palea

Data were collected after anthesis to hard dough stage or pre-ripening stage on spikelet with pubescence of lemma and palea and the observed lines were classified into five groups with codes according to guided descriptors as follows.

Absent or very weak-1,

Weak-3,

Medium-5, Strong-7 and

Very strong-9

3.12.1.20 Spikelet: Color of the tip of lemma

Data were collected after anthesis to hard dough stage or pre-ripening stage on spikelet with color of the tip of lemma and the observed lines were classified into six groups with codes according to guided descriptors as follows.

White-1, Yellowish-2, Brownish-3,

Red-4, Purple-5 and Black-6.

3.12.1.21 Spikelet: Awns in the spikelet

It was observed at flowering to maturity stage and normally a character of wild species of rice and grouped as descriptors.

Absent-1 and Present-9.

3.12.1.22 Spikelet: Length of the longest awn

It was observed at maturity stage and normally a character of wild species of rice and grouped as descriptors.

Very short (20 mm)-9.

3.12.1.23 Panicle: Distribution of awns

It was observed at flowering to maturity stage and normally a character of wild species of rice and grouped as descriptors.

Tip only-1, Upper half Whole length-5.

3.12.1.24 Panicle: Color of awns

It was observed at flowering to maturity stage and normally a character of wild species of rice and grouped as descriptors.

Yellow white-1, Brown-3,

Reddish-5, Purple-7 and Black-9.

3.12.1.25 Panicle: Attitude of branches

The compactness of the panicle was classified according to its mode of branching, angle of primary branches, and spikelet density by the following groups.

Erect (compact panicle)-1, Semi-erect (semi-compact panicle)-3,

Spreading (open panicle)-5, Horizontal-7 and Drooping-9.

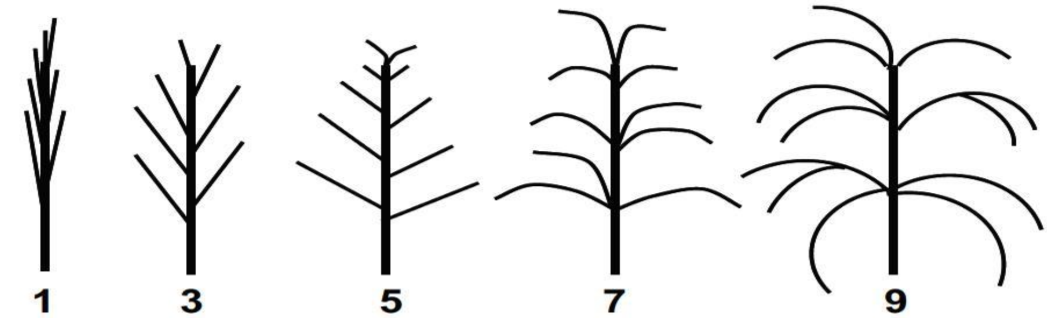


Figure 3. Attitude of panicle branches

3.12.1.26 Panicle: Exertion

Extent to which the panicle is exerted above the flag leaf sheath is known as panicle exertion. Data was collected at near maturity stage and the boro lines were classified into five groups with codes according to guided descriptors as follows.

Enclosed-1, Partly exerted-3 Just exerted-5,

Moderately exerted-7 and Well exerted-9.

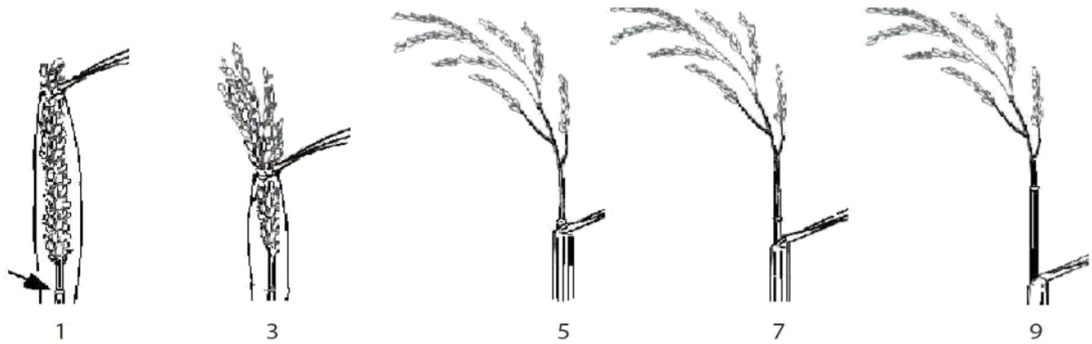


Figure 4. Panicle exertion.

3.12.1.27 Leaf Senescence: Penultimate

leaves are observed at the time of harvest. Data on leaf senescence were collected at the time of harvest and the observed lines were classified into three groups with codes according to guided descriptors as follows.

Late and slow (2 or more leaves retain green color at maturity)-1,

Intermediate-5 and Early and fast (leaves are dead at maturity)-9.

3.12.1.28 Decorticated Grain: Shape (length-width ratio of de-hulled grain)

Data were collected at the time of harvest and the observed lines were classified into five groups with codes according to guided descriptors as follows.

Round (L: W<1.5)-1,

Bold (L: W=1.5-2.0)-3,

Medium (L: W=2.1-2.5)-5,

Medium slender (L: W=2.6-3.0)-7 and

Slender (L: W>3.0)-9

3.12.1.29 Decorticated Grain (bran): Color

Data were collected at the time of harvest and the observed lines were classified into seven groups with codes according to guided descriptors as follows.

White-1, Light brown-2, Variegated brown-3,

Dark brown-4, Red-5 Variegated purple-6 and Purple-7.

3.12.1.30 Polished Grain: Size of white core or chalkiness (% of kernel area)

Data were collected at the time of harvest and the observed lines were classified into four groups with codes according to guided descriptors as follows.

Absent or very small-1,

Small (<10%)-3

Medium (11%-20%)-5 and

Large (>20%)-9

3.12.1.31 Decorticated Grain: Aroma

Data were collected at the time of harvest and the observed lines were classified into three groups with codes according to guided descriptors as follows.

Absent-1, Lightly present-5 and

Strongly present-9.

3.12.2 Quantitative Traits Evaluation

3.12.2.1 Stem: Culm diameter (from 5 mother tillers in the lowest internode)

Culm diameter of the stem was measured in millimeter scale at the lowest internode of the stem during flowering or late reproductive stage by using digital caliper and categorized as per descriptors.

Small (<5.0mm)-1

Medium (5.1-6.0mm)-3

Large (6.1-7.0mm)-5 and

Very large (>7.0 mm)-7

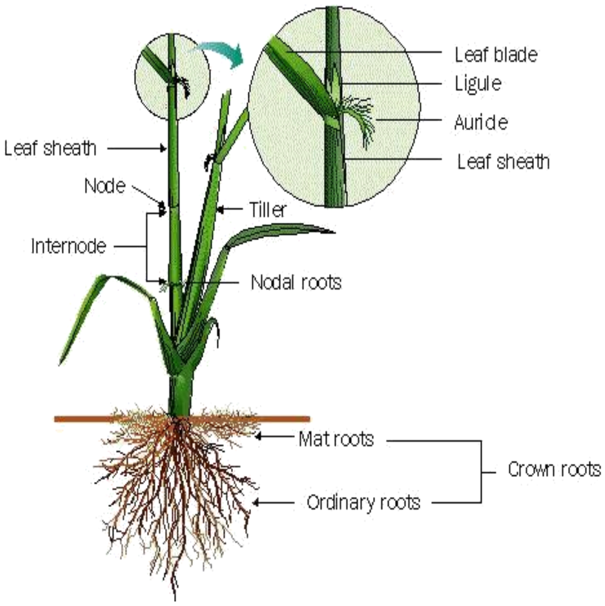


Figure 5. Morphology of a rice plant (vegetative stage)

3.12.2.2 Stem Length (culm length): Measure from the base of the plants to the neck of the panicles

Stem length (culm length) was measured in centimeter from the base of the plants to the neck of the panicles after flowering to maturity stage and categorized as per descriptors.

Very short (<40cm)-1,

Short (41-60cm)-3,

Medium (61-80cm)-5,

Long (81-110cm)-7 and

Very long (>110 cm)-9.

3.12.2.3 Panicle Length: Measured from the neck to the tip of the panicle of main tillers without awns

The mean length often randomly selected panicles of main tillers from ten hills were measured from neck to the tip of the panicle of main tiller without awn in centimeters. Data was collected at seven days after anthesis or full panicle exertion stage. According to their length, the observed boro lines were classified into four groups with codes.

Short (<20 cm)-3,

Medium (21-25cm)-5,

Long (26-30cm)-7 and

Very long (>30cm).

3.12.2.4 Panicle: Number of the effective tillers per plant

Effective tillers are the tillers which bears panicle and the total number of tillers were counted from each of the sample plants and the average was taken. Based on this character, all the lines were grouped into following groups.

Few (>6)-3, Medium (6-10)-5 and Many (>10)-7.

3.12.2.5 Time of Maturity

The number of days from date of sowing until 80% seeds become matured considering each replication was recorded on each individual plot and the lines were classified as per the guided descriptors.

Very early (>100 days)-1, Early (101-115 days)-3, Medium (116-135 days)-5, Late (136-150 days)-7 and

Very late (>150 days)-9.

3.12.2.6 Grain: Weight of 1000 fully developed grains (adjusted of 12% of moisture)

After threshing and recording the net yield, a random sample of fully grown 1000 seeds were counted and weighed at 12% moisture content to record the test weight. According to test weight, the lines were categorized into five different groups as following.

Very low (<15gm)-1,

Low (16-19gm)-3,

Medium (20-23gm)-5,

High (24-27gm)-7 and

Very high (>27 gm)-9.

3.12.2.7 Grain: Length (without dehulling)

Grain length was measured in mm and a digital caliper was used for clear visualization. Ten grains from every genotype were measured and the mean value was recorded. The lines were classified as per the guided descriptors.

Very short (<6.0mm)-1,

Short (6.1-7.0mm)-3,

Medium (7.1-8.0mm)-5,

Long (8.1-9.0mm)-7 and

Very long (>9.0mm)-9.

3.12.2.8 Sterile Lemma Length: Measure at post-harvest stage

Sterile lemma length was measured in mm and a digital caliper was used for clear visualization. Ten grains from every genotype were measured and the mean value was recorded. The lines were classified as per the guided descriptors.

Short (<1.5 mm)-1,

Medium (1.5-2.5mm)-3,

Long (2.6-3.0mm)-5 and

Very long (>3.0mm)-7.

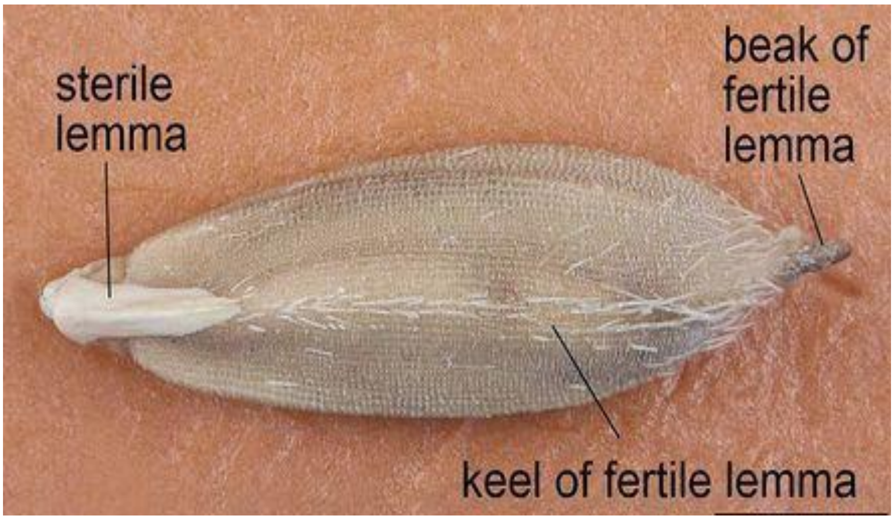


Figure 6. Rice grain with sterile lemma.

3.12.2.9 Decorticated Grain: Length (After dehulling, before milling)

Decorticated grain length was measured in mm and a digital caliper was used for clear visualization. Ten grains from every line were measured and the mean value was recorded. The lines were classified as per the guided descriptors.

Short (<5.5 mm)-1,

Medium (5.6-6.5mm)-3,

Long (6.6-7.5mm)-5 and

Very long (>7.5mm)-7.

3.12.3 Data collection for Estimation of variability

Some quantitative data were recorded on ten selected plants for each advanced line on the following characters:

I. **Days to 80% maturity**

Days to 80% Maturities of the crops of different combination were recorded considering the symptom such as moisture content of rice, color changing of the plant from greenish to straw colored appearance, color and hardness of the grain.

II. **Plant height (cm)**

The plant height was recorded in centimeter (cm) at the time of harvesting. The height was recorded from the ground level to the tip of the panicle.

III. **Number of total tillers per plant**

The number of panicles bearing total tillers were counted from each of the sample hills and average was taken.

IV. **Number of effective tillers per plant**

The number of effective tillers per plant was recorded as the number of panicles bearing tillers per plant and average value was recorded from ten plants.

V. **Panicle length (cm)**

The panicle length was measured with a meter scale from 10 selected plants and the average value was recorded as per plant.

VI. **Number of primary branches per panicle**

Primary branches were counted from one panicle of each of the randomly selected 10 plants and the average value was counted.

VII. **Number of secondary branches per panicle**

Secondary branches were counted from one panicle of each of the randomly selected 10 plants and the average value was recorded.

VIII. Number of filled grains per panicle

Presence of endosperm in spikelet was considered as filled grain and total number of filled grains present on main panicle was counted and average was taken.

IX. Number of unfilled grains per panicle

Absence of endosperm in spikelet was considered as unfilled grain and total number of unfilled grains present on main panicle was counted and average was taken.

X. Total number of spikelet per panicle

The total number of filled grains and unfilled grains were collected randomly from selected 10 plants of a plot and then average numbers of total spikelet per panicle was counted.

XI. 1000-seed weight (g)

One thousand seeds were counted randomly from cleaned seed lot and then weighted in grams and recorded.

XII. Yield per hectare (ton)

Grains taken from each unit plot were sun dried and weighted carefully and converted to ton per hectare.

3.12.4 Statistical Application

The qualitative and quantitative data in relation to morphological traits are just presented in tabular form for easier description according to the descriptors developed by BIOVERSITY INTERNATIONAL, IRRI AND WARDA-2007. The data were arranged as per IBPGR-IRRI formulation with the help of Microsoft-XL program.

3.12.4.1 Estimation of variability

Collected data on the ten lines were subjected to statistical analysis for each character, analysis of variance (ANOVA), mean, range were calculated by using Statistix-10 a software and then phenotypic and genotypic variance was estimated by the formula used by Johnson *et al.* (1955). Genotypic and phenotypic co-efficient of variation were calculated by the formula of Burton (1952).

Analysis of variance (ANOVA)

The analysis of variance (ANOVA) for all characters was carried out individually.

Source of variation	df	MSS	EMSS	F-Ratio
Replication (r)	r-1	M_1		M1/M3
Genotypes (g)	g- 1	M_2	$\delta^2 e + \delta^2 g$	M2/M3
Error(e)	(r-1) (g-1)	M_3	$\delta^2 e$	

Where,

r = Number of replications

g = Number of genotypes

df = degree of freedom

MSS = Mean sum of square

EMSS = Expected values of MSS

ii. Estimation of variance components

Genotypic and phenotypic variances were estimated according to the formula of Johnson *et al.* (1955).

a. Genotypic variance, $\delta^2 g = \frac{\text{MSG}-\text{MSE}}{r}$

Where, MSG = Mean sum of square for genotypes MSE = Mean sum of square for error and r = Number of replications

b. Phenotypic variance, $\boldsymbol{\delta^2 p = \delta^2 g + \delta^2 e}$

Where, $\delta^2 g$ = Genotypic variance,

$\delta^2 e$ = Environmental variance = Mean square of error

iii. Estimation of genotypic co-efficient of variation (GCV) and phenotypic coefficient of variation (PCV)

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated following formula as suggested by Burton (1952): Genotypic coefficient of variance (GCV) (%) = $\frac{\sqrt{\delta 2g}}{\bar{x}}$ x 100

Where, $\delta^2 g$= genotypic variance, $\bar{x}$= population mean

Phenotypic coefficient of variance (PCV) (%) = $\frac{\sqrt{\delta 2p}}{\bar{x}}$ x 100

Where, $\delta^2 p$ = phenotypic variance, $\bar{x}$= population mean

The magnitude of coefficient of variation was categorized as high (> 20%), moderate (20% - 10%) and low (< 10%).

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted with a view to characterize and evaluate ten advanced Boro rice lines as per the guideline developed by Biodiversity International, IRRI and WARDA-2007. Data were recorded on 35 qualitative and 10 quantitative characters. Variability parameters were estimated on 12 yield and yield contributing characters. Results have been compiled in tabular form according to descriptors and described in the following headings;

4.1 Characterization Based on Qualitative Characteristics

4.1.1 Leaf Sheath: Anthocyanin color

Considering the leaf sheath anthocyanin coloration observed from the lines were categorized as absent-1 and present-2 according to guided description as per following chart. But no coloration was found in this investigation (Table 3). A pictorial view of leaf sheath anthocyanin color is present in plate no. 5.

4.1.2 Leaf Color

Leaf color from the observed lines were categorized in seven groups like pale green-1, green-2, dark green-3, purple tip-4, purple margins-5, purple blotch-6 and purple-7 according to guided descriptors as follows. All lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed green color. Others six color were absent in all lines (Table 3). Pictorial view of leaf color is present in plate 6.

4.1.3 Penultimate Leaf: Anthocyanin coloration of auricles and collar

On the basis of penultimate leaf anthocyanin coloration of auricles and collar, boro lines were classified as absent-1 and present-2. All the ten lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) absent penultimate leaf anthocyanin coloration of auricles and collar that means there was no significant difference among the lines (Table 3). A pictorial view of anthocyanin coloration of auricles and color of penultimate leaf is present in Plate 7.

4.1.4 Penultimate Leaf: Ligule

On the basis of penultimate leaf ligule shape, boro lines were classified as absent-1 and present-9. All lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) presence ligule of the penultimate leaf that means there was no significant difference among the lines (Table 3).

4.1.5 Penultimate Leaf: Shape of the ligule

On the basis of ligule shape of penultimate leaf, boro lines were classified as truncate-1, acute to acuminate-2 and split or two-cleft-3 type. But our all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were two-cleft type that means there was no significant difference among the lines in this character (Table 3). According to IRRI most of the cultivated rice have two-cleft type ligule shape and wild type genotypes may show others type. From our observation the two-cleft type ligule was found. A pictorial view of shape of the ligule of penultimate leaf is present in Plate 8.

4.1.6 Male Sterility

Male sterility was observed at anthesis period of rice and grouped as per descriptors. On the basis of male sterility, boro lines were classified as absent-1, CMS-3, TGMS-5, PGMS-7 and P (T) GMS-9. But all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, and L10) had absence of male sterility that means there was no significant difference among the lines (Table 3).

Table 3: Characterization on qualitative characters

Lines	Leaf Sheath: Anthocyanin color	Leaf Color	Penultimate Leaf: Anthocyanin coloration	Penultimate Leaf: Ligule	Penultimate Leaf: Shape of the ligule	Male Sterility
L1	-	++	-	+	++	-
L2	-	++	-	+	++	-
L3	-	++	-	+	++	-
L4	-	++	-	+	++	-
L5	-	++	-	+	++	-
L6	-	++	-	+	++	-
L7	-	++	-	+	++	-
L8	-	++	-	+	++	-
L9	-	++	-	+	++	-
L10	-	++	-	+	++	-
Comments	No Color	Green	Absent	Present	Two cleft	Absent

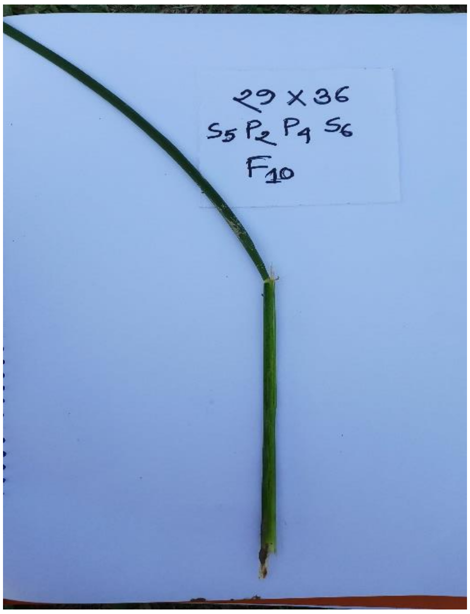
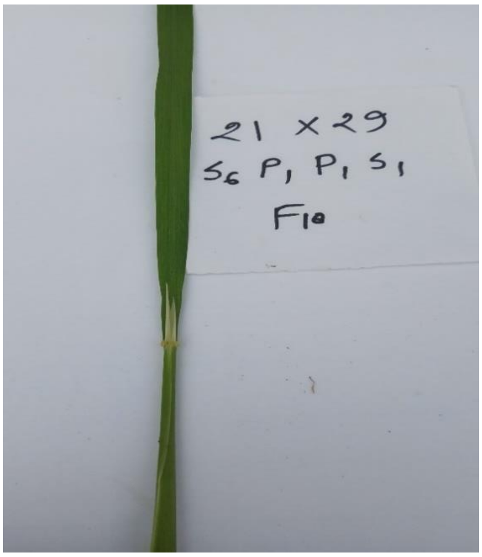


Plate 5: Leaf Sheath: Anthocyanin color

Plate 6: Leaf Color



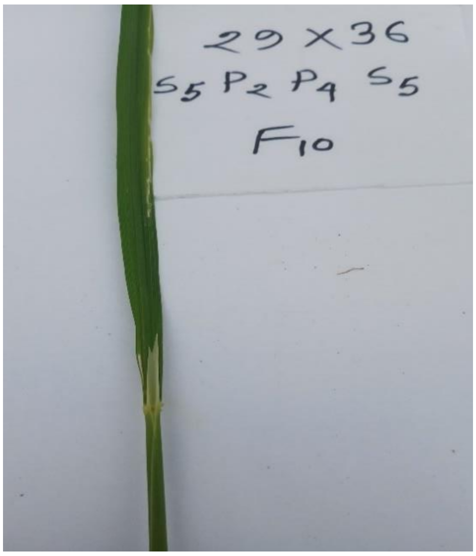


Plate 7: Penultimate Leaf: Anthocyanin coloration of auricles and collar

Plate 8: Penultimate Leaf: Shape of the ligule

4.1.7 Microscopic observation of Pollen with I2-KI solution

It was observed at anthesis period of rice using microscope and the boro lines were classified into eight groups with codes according to guided descriptors as per follows. Completely sterile with TA pollen-1, completely sterile with 80% TA pollen-2, completely sterile with 50% TA pollen-3, sterile (91-99%)-4, partial sterile (31-70%)-5, partial fertile (31-70%)-6, fertile (21-30%)-7 and fully fertile (0-20%)-8. In this situation all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were fertile that means there was no significant difference among the lines (Table 4).

4.1.8 Lemma and Palea: Anthocyanin color

On the basis of lemma and palea anthocyanin coloration the observed lines were categorized as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9 as presented according to descriptors. Lemma and palea combinedly indicates the seed coat color actually. But all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed no anthocyanin coloration of lemma and palea or very weak anthocyanin coloration of lemma and palea for seed coat color (Table 4, Plate 9).

4.1.9 Lemma: Anthocyanin coloration of area below apex

On the basis of lemma anthocyanin coloration of area below apex the observed lines were categorized as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9 as presented according to descriptors. Lemma indicates the seed coat color actually. But all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed no anthocyanin coloration of area below apex of lemma or very weak anthocyanin coloration of area below apex of lemma for seed coat color that means there was no significant difference among the lines (Table 4, Plate 10).

4.1.10 Lemma: Anthocyanin coloration of apex

On the basis of lemma anthocyanin coloration of apex, the observed lines were categorized as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9 as presented according to descriptors. Lemma indicates the seed coat color accurately. But all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed no anthocyanin coloration of apex of lemma or very weak anthocyanin coloration of apex of lemma for seed coat color that means there was no significant difference among the lines (Table 4).

4.1.11 Color of Stigma

Data were observed at anthesis period using a hand lens or magnifying glass and the boro lines were classified into five groups with codes as white -1, light green2, yellow-3, light purple-4 and purple-5. All the ten lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed white color of stigma that means there was no significant difference among the lines. Light green, yellow, light purple and purple color of stigma were not observed (Table 4, Plate 11).

4.1.12 Stem: Anthocyanin coloration of nodes

Data were collected after flowering to near maturity stage on stem anthocyanin coloration of nodes and the lines were classified into two groups with codes according to guided descriptors as absent-1 and present-9. In this case all the ten lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed no anthocyanin coloration of nodes that means there was no significant difference among the lines (Table 4). A pictorial view of anthocyanin coloration of nodes is present in plate 12.

Table 4: Characterization on qualitative characters

Lines	**Micros. obs. of Pollen**	**Lemma and Palea: Antho. color**	**Lemma: Antho. coloration of area below apex**	**Lemma: Antho. coloration of apex**	**Color of Stigma**	**Stem: Antho. coloration of nodes**
L1	+	-	-	-	+	-
L2	+	-	-	-	+	-
L3	+	-	-	-	+	-
L4	+	-	-	-	+	-
L5	+	-	-	-	+	-
L6	+	-	-	-	+	-
L7	+	-	-	-	+	-
L8	+	-	-	-	+	-
L9	+	-	-	-	+	-
L10	+	-	-	-	+	-
Comments	Fertile	Absent	Absent	Absent	White	Absent

Plate 9: Lemma and Palea: Anthocyanin color

Plate 10: Lemma: Anthocyanin coloration of area below apex

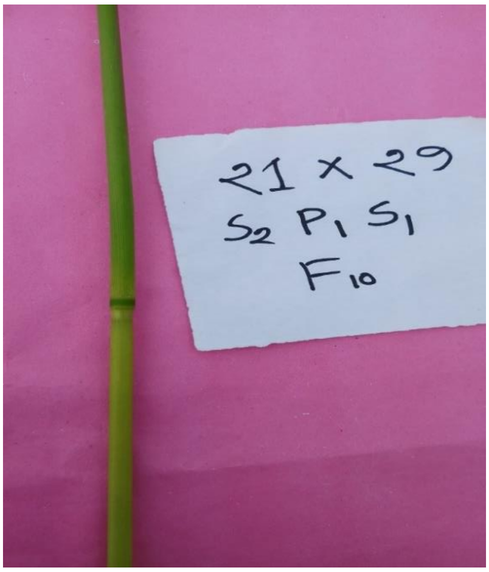


Plate 11: Color of Stigma

Plate 12: Stem: Anthocyanin coloration of nodes

4.1.13 Stem: Intensity of anthocyanin coloration of nodes

Data were collected after flowering to near maturity stage on stem anthocyanin coloration of nodes and the boro lines were classified into four groups with codes according to guided descriptors as weak-3, medium-5, strong-7 and very strong-9. In this case there was weak anthocyanin coloration of nodes on the stem present in all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) that means there was no significant difference among the lines. So, intensity of anthocyanin coloration of nodes on the stem of all genotypes was weak (Table 5, Plate 13).

4.1.14 Stem: Anthocyanin coloration of internodes

Data were collected at near coloration maturity stage on stem anthocyanin coloration of internodes and the boro lines were classified into five groups with codes according to guided descriptors as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9. In this case all the ten lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed no anthocyanin coloration of internodes that means there was no significant difference among the lines (Table 5). A pictorial view of anthocyanin coloration of internodes is present in Plate 14.

4.1.15 Panicle Curvature of Main Axis (i.e., recurrent main axis)

Data were collected at near maturity stage and the lines were classified into four groups with codes according to guided descriptors as absent or very weak (upright)-1, weak (semi-upright)-3, medium (slightly drooping)-5 and strong (strongly dropping)-7. In this case all ten lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were strong type of panicle curvature of main axis (Table 5). Pictorial view of panicle curvature of main axis is present in Plate 15.

4.1.16 Spikelet: Color of the tip of lemma

Data were collected after anthesis to hard dough stage or pre-ripening stage on spikelet with color of the tip of lemma and the boro lines were classified into six groups with codes according to guided descriptors as white-1, yellowish-2, brownish-3, red-4, purple-5 and black-6. In this case all the ten lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed yellowish color type of the tip of lemma that means there was no significant difference among the lines. White, brownish, red, purple and black coloration of the tip of lemma was not observed (Table 5, Plate 16).

4.1.17 Spikelet: Awns in the spikelet

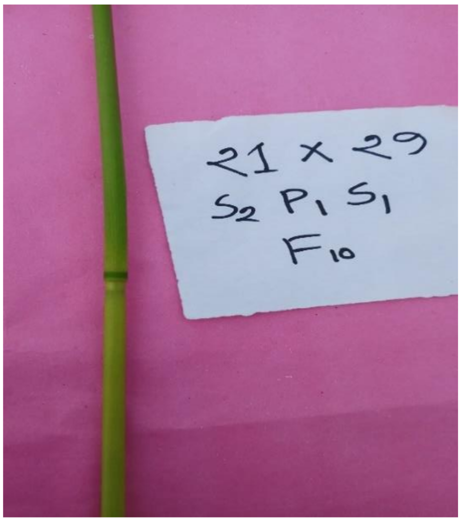
It was observed flowering to maturity and normally a character of wild species of rice and grouped as absent-1 and present-9. But all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were showed no awns in the spikelet.

4.1.18 Spikelet: Length of the longest awn

It was observed at maturity stage and normally a character of wild species of rice and grouped as per descriptors such as very short-(<2 mm)-1, (short 2-5mm)-3, (medium 5-10mm)-5, (long 11-20mm)-7, and (very long (>20mm)-9. In this case there was no awns in the spikelet present in all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10). So, length of the longest awn in the spikelet of all lines was not present.

Table 5: Characterization on qualitative characters

Lines	Stem: coloration of nodes	Stem: coloration of internodes	Panicle curvature of Main Axis	Spikelet: Color of the tip of lemma	Spikelet: Awns in the spikelet	Spikelet: Length of the longest awn
L1	+	-	++	+	-	-
L2	+	-	++	+	-	-
L3	+	-	++	+	-	-
L4	+	-	++	+	-	-
L5	+	-	++	+	-	-
L6	+	-	++	+	-	-
L7	+	-	++	+	-	-
L8	+	-	++	+	-	-
L9	+	-	++	+	-	-
L10	+	-	++	+	-	-
Comments	Weak	Absent	Strong	Yellowish	Absent	Absent



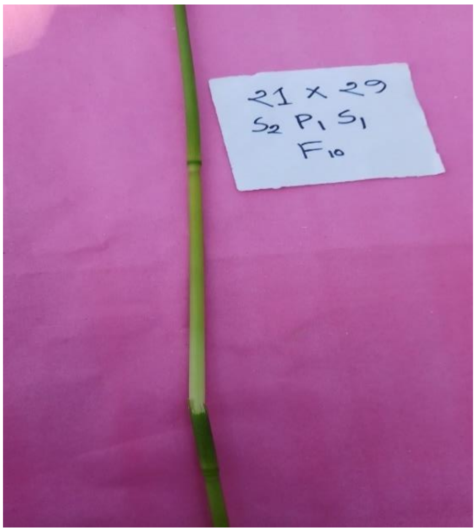


Plate 13: Stem: Intensity of anthocyanin coloration of nodes

Plate 14: Stem: Anthocyanin coloration of internodes

Plate 15: Panicle Curvature of Main Axis (i.e., recurrent main axis)

Plate 16: Spikelet: Color of the tip of lemma

4.1.19 Panicle: Distribution of awns

It was observed at flowering to maturity stage and normally a character of wild species of rice and grouped as per descriptors such as tip only-1, upper half only-3 and whole length-5. In this case there was no awns in the spikelet present in all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10). So, distribution of awns in the panicle of all lines was not present.

4.1.20 Panicle: Color of awns

It was observed at flowering to maturity stage and normally a character of wild species of rice and grouped as per descriptors such as yellow white-1, brown-3, reddish-5, purple-7 and black-9. In this case there was no awns in the spikelet present in all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10). So, color of awns in the panicle of all lines was not present.

4.1.21 Panicle: Attitude of branches

The compactness of the panicle was classified according to its mode of branching, angle of primary branches, and spikelet density in three groups as erect (compact panicle)-1, semi-erect (semi-compact panicle)-3 and spreading (open panicle)-5 type panicle where all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed spreading type panicle. Erect or sem- erect typed panicles were not found among the lines (Table 6). Pictorial view of attitude of branches of panicle is present in Plate 17.

4.1.22 Decorticated Grain: Shape (length-width ratio of de-hulled grain)

Data were collected at the time of harvest and the boro lines were classified into five groups with codes according to guided descriptors as per follows round (L: W<1.5)-1, Bold (L:W=1.5-2.0)-3, Medium (L:W=2.1-2.5)-5, Medium slender (L:W=2.6-3.0)-7 and Slender (L:W>3.0)-9. There where all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed slender type grain shape. Round, bold, medium and medium slender type decorticated grain were not found among the lines (Table 6). Pictorial view of decorticated grain shape is present in plate 18.

4.1.23 Decorticated Grain (bran): Color

Data were collected at the time of harvest and the lines were classified into seven groups with codes according to guided descriptors as per follows white-1, light brown-2, variegated brown-3, dark brown-4, red-5, variegated purple-6 and purple-7 where all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed white colored decorticated grain (bran). Light brown, variegated brown, dark brown, red, variegated purple and purple decorticated grain (bran) coloration was not found among the lines (Table 6).

4.1.24 Decorticated Grain: Aroma

Data were collected at the time of harvest and the boro lines were classified into three groups with codes according to guided descriptors as per follows absent-1, lightly present-5 and strongly present-9. In this case all the ten lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed no aroma present in decorticated grain that means there was no significant difference among the lines (Table 6).

Table 6: Characterization on qualitative characters

Lines	Panicle: Distrib. of awns	Panicle: Color of awns	Panicle: Attitude of branches	Decort. Grain: Shape	Decort. Grain: Color	Decort. Grain: Aroma
L1	+	-	++	+++	+	-
L2	+	-	++	+++	+	-
L3	+	-	++	+++	+	-
L4	+	-	++	+++	+	-
L5	+	-	++	+++	+	-
L6	+	-	++	+++	+	-
L7	+	-	++	+++	+	-
L8	+	-	++	+++	+	-
L9	+	-	++	+++	+	-
L10	+	-	++	+++	+	-
Comments	Present	Absent	Spreading	Slender	White	Absent

Plate 17: Panicle: Attitude of branches

Plate 18: Decorticated Grain: Shape (length-width ratio of de-hulled grain)

4.1.25 Penultimate Leaf Pubescence

Based on penultimate leaf pubescence our observed lines were categorized into five groups as absent or very weak-1, weak or only on the margins-3, medium hairs on the medium portion of the leaf-5, strong hairs on the leaf blade-7 and very strong-9 nature. Three lines (L1, L8 and L10) were absent or very weak type, six lines (L3, L4, L5, L6, L7 and L9) were strong hairs on the leaf blade type and only one-line L2 showed very strong type. Weak or only on the margins and medium hairs on the lower portion of the leaf were not found in any lines (Table 7).

Table 7: Grouping based on penultimate leaf pubescence

Types	**Code**	**Lines**
Absent or very weak	1	L1, L8 and L10
Weak or only on the margins	3	Nil
Medium hairs on the lower portion of the leaf	5	Nil
Strong hairs on the leaf blade	7	L3, L4 L5, L6, L7 and L9
Very strong	9	L2

4.1.26 Flag Leaf: Attitude of the blade

Based on angle of attachment between the flag leaf blade and the main panicle axis the observed lines were categorized in four groups like erect-1, semi-erect-3, hosrizontal-5, reflexed or descending-7. Here seven lines (L1, L2, L3, L5, L7, L8, and L19) showed erect type flag leaf and rest three lines (L4, L6 and L10) showed intermediate or semi-erect type flag leaf (Table 8).

Table 8: Grouping based on attitude of the blade of flag Leaf

Types	**Code**	**Lines**
Erect	1	L1, L2, L3, L5, L7, L8, L9 and
Semi-erect	3	L4, L6, L10
Horizontal	5	Nil
Reflexed or descending	7	Nil

4.1.27 Stigma Exertion

Data were observed at anthesis period using a hand lens or magnifying glass and the boro lines were classified into five groups with codes according to guided descriptors as no or a few (>5%)-1, low (5-20%)-3, medium (21-40%)-5, high (41-60%)-7 and very high (>61%)-9. In this case two lines (L9 and L19) were showed no or a few type stigma exertion, three lines (L4, L7 and L18) were showed low type stigma exertion, two lines (L3 and L10) were showed medium, one line (L2) were showed high type and two lines (L1 and L6) were showed very high type for exertion of stigma (Table 9). A pictorial view of stigma exertion of rice is present in Plate 19.

Table 9: Grouping based on stigma exertion

Types	**Code**	**Lines**
No or a few (>5%)	1	L5, L9
Low (5-20%)	3	L4, L7, L8
Medium (21-40%)	5	L3, L10
High (41-60%)	7	L2
Very high (>61%)	9	L1, L6

4.1.28 Spikelet: Pubescence of lemma and palea

Data were collected after anthesis to hard dough stage or pre-ripening stage on spikelet with pubescence of lemma and palea and the boro lines were classified into five groups with codes according to guided descriptors as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9. In this case eight lines (L2, L3, L4, L5, L6, L7, L8 and L10) were observed weak type and two lines (L1 and L9) were observed medium type pubescence of lemma and palea. (Table 10). Pictorial view of pubescence of lemma and palea is present in Plate 21.

Table 10: Grouping based on pubescence of lemma and palea of the spikelet

Types	Code	Lines
Absent or very weak	1	Nil
Weak	3	L2, L3, L4, L5, L6, L7, L8 and L10
Medium	5	L1, L9
Strong	7	Nil
Very strong	9	Nil

Plate 19: Stigma Exertion

Plate 20: Flag Leaf: Attitude of the blade

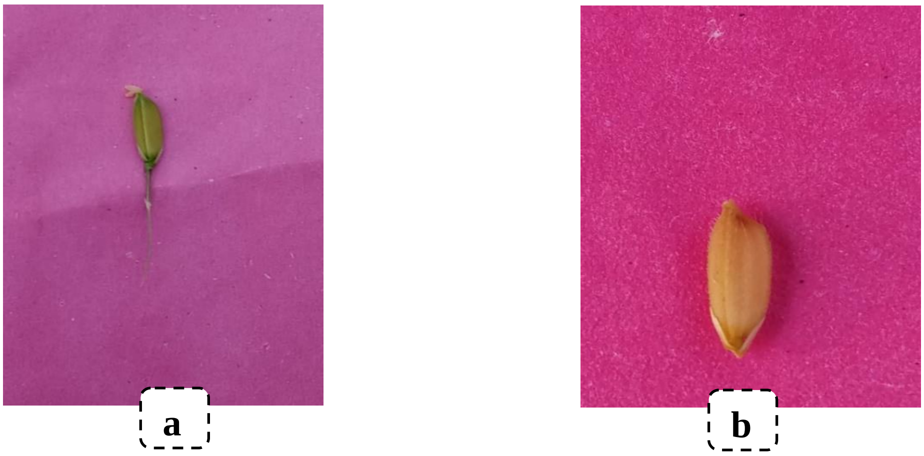


Plate 21: Spikelet: Pubescence of lemma and palea (a, b)

4.1.29 Panicle: Exertion

Extent to which the panicle is exerted above the flag leaf sheath is known as panicle exertion. Data were collected at near maturity stage and the boro lines were classified into five groups with codes according to guided descriptors as enclosed-1, partly exerted-3, just exerted-5, moderately exerted-7 and well exerted-9. In this case three lines (L3, L5 and L9) were observed just exerted type, one line (L6) was observed moderately exerted type and six lines (L1, L2, L4, L7, L8 and L10) were observed well exerted type of the panicle exertion. Enclosed and partly exerted type of panicle exertion were not found (Table 11, Plate 22).

Table 11: Grouping based on panicle exertion

Types	Code	Lines
Enclosed	1	Nil
Partly exerted	3	Nil
Just exerted	5	L3, L5, L9
Moderately exerted	7	L6
Well exerted	9	L1, L2, L4, L7, L8, and L10

Plate 22: Panicle: Exertion

4.1.30 Leaf Senescence: Penultimate leaves are observed at the time of harvest.

Data were collected at the harvest and the boro lines were classified into three groups with codes according to guided descriptors as per follows. Late and slow (2 or more leaves retain green color at maturity)-1, intermediate-5 and early and fast (leaves are dead at maturity)-9. There were six lines (L1, L5, L6, L8, L9 and L10) showed late and slow (2 or more leaves retain green color at maturity) level and rest four lines (L2, L3, L4 and L7) showed intermediate type of leaf senescence. Early and fast (leaves are dead at maturity) type of leaf senescence was not found among the lines (Table 12).

Table 12: Grouping based on leaf senescence of penultimate leaves are observed at the time of harvest

Types	**Code**	**Lines**
Late and slow (2 or more leaves retain green color at maturity)	1	L1, L5, L6, L8, L9 and L10
Intermediate	5	L2, L3, L4, L7
Early and fast (leaves are dead at maturity)	9	Nil

4.1.31 Polished Grain: Size of white core or chalkiness (% of kernel area)

Data were collected at the time of harvest and the boro lines were classified into four groups with codes according to guided descriptors as per follows absent or very small-1, small (>10%)-3, medium (11-20%)-5, large (>20%)-7 where eight lines (L2, L3, L4, L5, L6, L8, L9 and L10) showed absent or very small size of white core or chalkiness (% of kernel area) of polished grain and rest two lines (L1 and L7) showed small size of white core or chalkiness (% of kernel area) of polished grain. Medium and large small size of white core or chalkiness (% of kernel area) of polished grain were not found among the lines (Table 13)

Table 13: Grouping based on size of white core or chalkiness (% of kernel area) of polished grain

Types	Code	Lines
Absent or very small	1	L2, L3, L4, L5, L6, L8, L9 and L10
Small (<10%)	3	L1, L7
Medium (11-20%)	5	Nil
Large (11-20%)	7	Nil

4.2 Characterization Based on Quantitative Characteristics

4.2.1 Time of heading (50% of the plants with heads)

Date on which 50% of panicle emergence is done on the rice field is known as heading. Time of 50% heading of the observed lines ranged from 115 days to 102 days with a mean value of 106 days (Appendix-V). On the basis of time of 50% heading, advance boro lines were classified into five groups viz. very early (<70days)-1, early (70-85days)-3, medium (85-105days)-5, late (105-120days)-7, very late (>120 days)-9. Five lines (L3, L7, L8, L9 and L0) showed medium and rest of five lines (L1, L2, L4, L5 and L6) showed late but no lines were found as very early, early and very late type for 50% heading formation (Table 14). A pictorial view of time of heading (50% of the plants with heads) is present in plate 23.

Table 14. Categorization and grouping based on time of heading

Groups	Scale	Code	Lines
Very early	<70	1	Nil
Early	70-85	3	Nil
Medium	86-105	5	L3, L7, L8, L9 and L10
Late	106-120	7	L1, L2, L4, L5, L6,
Very Late	>120	9	Nil
Range	102 days (L4) - 115 days (L10)		
Average	106 days		

Plate 23. Time of heading (50% of plants with heads).

4.2.2 Stem: Culm diameter (from 5 mother tillers in the lowest internode)

Culm diameter of the stem was measured in millimeter scale at the lowest internode of the stem during flowering or late reproductive stage. Culm diameter of observed lines ranged from 3.70 mm to 6.10 mm with a mean value of 4.54 mm (Appendix-V). On the basis of this character, the lines were categorized into four groups as small (<5mm)-1, medium (5.1-6.0mm)-3, large (6.1-7.0mm)-5, very large (>7.0 mm)-7 as the guided descriptors where there was no very large type line. On the other hand, seven small type lines (L1, L2, L4, L5, L8, L9 and L10) and medium type line (L3) and rest of two lines (L6 and L7) were found large type (Table 15).

Table 15. Categorization and grouping based on culm diameter

Groups	Scale	Code	Lines
Small	<5.0 mm	1	L1, L2, L4, L5, L8, L9 and L10
Medium	5.1-6.0 mm	3	L3
Large	6.1-7.0 mm	5	L6, L7,
Very Large	>7.0 mm	7	Nil
Range	3.70 mm (L4) - 6.10 mm (L6)		
Average	4.54 mm		

4.2.3 Stem Length (culm length): Measure from the base of the plants to the neck of the panicles

Culm length means the length of a stem from ground level to panicle base. Stem length (culm length) was measured from the base of the plants to the neck of the panicles after flowering to maturity stage. Culm lengths of observed lines ranged from 62.43 cm to 83.56 cm with a mean value of 72.32 cm (Appendix-V). On the basis of this character, the lines were categorized into five groups as very short (<40cm)-1, short (41-60cm)-3, medium (61-80cm)-5, large (81-110cm)-7 and very large (>110cm)-9 as the guided descriptors where there was no very short type, short and very long type lines. On the other hand, eight medium type lines (L1, L2, L4, L5, L6, L7, L9 and L10) and two long type lines (L3 and L8) were found (Table 16).

Table 16. Categorization and grouping based on culm length

Groups	Scale	Code	Lines
Very short	<40 cm	1	Nil
Short	41-60 cm	3	Nil
Medium	61-80 cm	5	L1, L2, L4, L5, L6, L7, L9 and L10
Long	81-110cm	7	L3, L8
Very long	>110 cm	9	Nil
Range	62.43 cm (L2) - 83.56 cm (L8)		
Average	72.32 cm		

4.2.4 Panicle Length: Measured from the neck to the tip of the panicle of main tillers without awns

For panicle length randomly selected panicles of main tillers from ten hills was measured from neck to the tip of the panicle of main tiller without awn in centimeters. Panicle length of observed lines ranged from 23.90 cm to 26.75 cm with a mean value of 24.95 cm (Appendix-V).

Table 17. Categorization and grouping based on panicle length

Groups	Scale	Code	Lines
Short	<20 cm	1	Nil
Medium	21-25 cm	5	L1, L4, L6, L7, and L10
Long	26-30 cm	7	L2, L3, L5, L8, L9
Very long	>30 cm	9	Nil
Range	23.90 cm (L10) - 26.75 cm (L5)		
Average	24.95 cm		

Data was collected at seven days after anthesis or full panicle exertion stage. On the basis of this character, the lines were categorized into four groups as short (<20cm)-3, medium (21-25cm)-5, long (26-30cm)-7 and very long (>30cm)-9 as the guided descriptors where there were no short type and very long type lines. Five lines (L1, L4, L6, L7 and L10) were found medium type and rest five lines were found long type (Table 17).

4.2.5 Panicle: Number of the effective tillers per plant

The number of effective tillers per plant of the observed lines ranged from 14 tillers to 11 tillers with a mean value of 12 tillers (Appendix-V) and considering this character, the observed lines were categorized as few (>6), medium (6-10) and many (>10) effective tillers per plant. There were no lines showed few and medium types of effective tillers per plant. All lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed many types of effective tillers per plant (Table 18).

Table 18. Categorization and grouping based on number of effective tillers per plant

Groups	Scale	Code	Lines
Few	<6 tillers	3	Nil
Medium	6-10 tillers	5	Nil
Many	>10 tillers	7	L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10
Range	14 tillers (L2) - 11 tillers (L3)		
Average	12 tillers		

4.2.6 Time of Maturity

Time of maturity was calculated as days required from sowing to maturity. Time of maturity of the observed lines ranged from 134 days to140 days with a mean value of 138 days (Appendix-V) and on the basis of this character, all the lines were classified into five groups as very early (>100 days), early (101-115 days), medium (116-135 days), late (136-150 days) and very late (>150 days).

Table 19. Categorization and grouping based on time of maturity

Groups	Scale	Code	Lines
Very early	>100	1	Nil
Early	101-115	3	Nil
Medium	116-135	5	L1
Late	136-150	7	L2, L3, L4, L5, L6, L7, L8, L9 and L10
Very Late	>150	9	Nil
Range	134 days (L1) - 140 days (L8)		
Average	138 days		

There were no lines showed very early, early and very late maturity of plant. On the other hand, one line (L1) showed medium type maturity of plants and rest nine lines (L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed late type maturity of plants (Table 19).

4.2.7 Grain: Weight of 1000 fully developed grains (adjusted of 12% of moisture)

Thousand grain weight of the observed lines ranged from 21.90 g to 25 g with a mean value of 22.87 g (Appendix-V) and considering this character, the lines were grouped as four types such as very low (<15mg)-1, low (16-19g)-3, medium (20-23g)-5, high (24-27g)-7 and very high (>27 g)-9. In this situation, there was no lines showed very low, low and very high type of 1000 grain weight. On the other hand, six lines (L1, L2, L4, L5, L6 and L9) showed medium type of 1000 grain weight, four lines (L3, L7, L8 and L10) showed high type of 1000 grain weight (Table 20).

Table 20. Categorization and grouping based on thousand grain weight (adjusted of 12% of moisture)

Groups	Scale	Code	Lines
Very Low	<15 g	1	Nil
Low	16-19 g	3	Nil
Medium	20-23 g	5	L1, L2, L4, L5, L6, L9 and
High	24-27 g	6	L3, L7, L8, L10
Very High	>27 g	7	Nil
Range	21.90 g (L9) - 25 g (L8)		
Average	22.87 g		

4.2.8 Grain: Length (without dehulling)

Grain length was measured in mm and a digital caliper was used for clear visualization. Ten grains from every line were measured and the mean value was recorded. Grain length of the lines ranged from 8.08 mm to 9.59 mm with a mean value of 8.92 mm (Appendix-V). On the basis of grain length, the observed lines were grouped as very short (<6.0mm)-1, short (6.1-7.0mm)-3, medium (7.1-8.0)-5, long (8.1-9.0mm)-7 and very long (>9.0 mm)-9. Five lines (L3, L4, L5, L7 and L19) were recorded as long and rest five lines (L1, L2, L6, L8 and L10) as very long (Table 21). No lines were found as very short, short and medium type. Pictorial view of grain length is present in Plate 24 and 25.

Table 21. Categorization and grouping based on grain length (without dehulling)

Groups	Scale	Code	Lines
Very Short	<6.0 mm	1	Nil
Short	6.1-7.0 mm	3	Nil
Medium	7.1-8.0 mm	5	Nil
Long	8.1-9.0 mm	7	L3, L4, L5, L7, L9 and
Very Long	>9.0 mm	9	L1, L2, L6, L8, L10
Range	8.08 mm (L5) - 9.59 mm (L10)		
Average	8.92 mm		

Plate 24. Very long type grain.

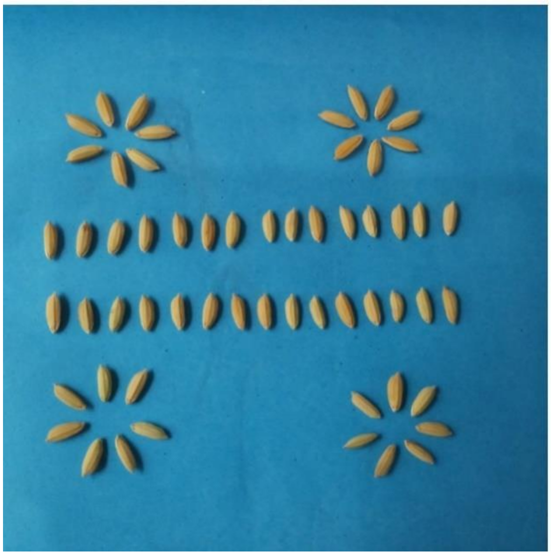


Plate 25. Long type grain.

4.2.9 Sterile Lemma Length: Measure at postharvest stage

Ten grains from every line were measured and the mean value was recorded. Sterile lemma length of the lines ranged from 1.8 mm to 2.5 mm with a mean value of 1.96 mm (Appendix-V). On the basis of sterile lemma length, the observed lines were grouped as short (<1.5mm)-1, medium (1.2-2.5mm)-3, long (2.6-3.0mm)-5 and very long (>3.0 mm)-7. All lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were recorded as medium sterile lemma length (Table 22). No lines were found as short type, long type and very long type.

Table 22. Categorization and grouping based on sterile lemma length

Groups	**Scale**	**Code**	**Lines**
Short	<1.5 mm	1	Nil
Medium	1.5-2.5 mm	3	L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10
Long	2.6-3.0 mm	5	Nil
Very Long	>3.0 mm	7	Nil
Range	1.8 mm (L4) - 2.5 mm (L10)		
Average	1.96 mm		

4.2.10 Decorticated Grain: Length (After dehulling, before milling)

Decorticated grain length was measured in mm and a digital caliper was used for clear visualization. Ten grains from every line were measured and the mean value was recorded. Decorticated grain length of lines ranged from 5.69 mm to 7.03 mm with a mean value of 6.46 mm (Appendix-V). On the basis of decorticated grain length, the observed lines were grouped as short (<5.5mm)-1, medium (5.6-6.5mm)-3, long (6.6-7.5mm)-5 and very long (>7.5 mm)-7. Four lines (L3, L5, L7 and L9) were recorded as medium type decorticated grain length, six lines (L1, L2, L4, L6, L8 and L10) as long type decorticated grain length (Table 23). No lines were found as short and very long type decorticated grain length.

Table 23. Categorization and grouping based on decorticated grain length

Groups	Scale	Code	Lines
Short	<5.5 mm	1	Nil
Medium	5.5-6.5 mm	3	L3, L5, L7, L9
Long	6.6-7.5 mm	5	L1, L2, L4, L6, L8and L10
Very Long	>7.5 mm	7	Nil
Range	(L5) 5.69 mm - (L10) 7.03 mm		
Average	6.46 mm		

4.3 Variability Among the Ten Advance Lines of Boro Rice

Genetic variability among these traits is important for selecting desirable types and best lines for further trial. The analysis of variance (ANOVA) of the data on different yield components and yield of ten advance boro rice lines are given in Table 24. Phenotypic variance, genotypic variance, phenotypic coefficient of variation and genotypic coefficient of variation for different yield related characters are presented in Table 26.

Table 24: Analysis of variances for twelve important characters of ten advanced boro rice lines.

Source of variance	Df	Mean sum of square											
		Character											
		DM	PH (cm)	NTT	NET	LP	NPBP	NSBP	TSP	NFGP	NUFGP	TSW (gm)	Y/H (t/ha)
Line	9	10.50**	243.93**	4.62**	4.22**	1.87**	3.78**	24.26**	581.09**	589.11**	66.83**	3.05**	1.27**
Replication	2	18.30	71.01	0.60	0.04	0.26	0.65	46.31	60.27	87.80	4.76	1.77	0.59
Error	18	3.00	6.66	2.58	2.25	1.08	0.98	4.44	104.64	111.33	6.45	1.53	0.50

**= Significant at 1% level.

DM = days to maturity, PH = plant height, NTT = number of total tillers per plant, NET = number of effective tillers per plant, LP = panicle length, NPBP = number of primary branches per panicle, NSBP = number of secondary branches per panicle, TSP = total number of spikelet per panicle, NFG/P = number of filled grains per panicle, NUFGP = number of filled grains per panicle, TSW = thousand seed weight, Y/H = yield per hectare.

Table 25: Mean performance of ten advanced boro rice lines in respect of twelve important characters.

Line	DM	PH	NTT	NET	LP (cm)	NPBP	NSBP	NFG/P	NUFG/P	TSP	TSW (gm)	Y/H (t/ha)
L1	136.33 bcd	92.25 c	13.57 abc	13.70 abcd	24.97 ab	9.13 d	32.17 bc	150.40 d	20.30 b	170.70 cd	22.44 bc	7.87 bcd
L2	136.67 bcd	88.84 c	14.33 ab	14.30 a	25.34 ab	9.63 cd	32.43 bc	156.17 cd	12.93 cd	169.10 cd	22.91 abc	8.24 abcd
L3	136.33 bcd	111.50 a	11.30 c	11.33 d	25.20 ab	11.57 a	35.73 ab	169.50 bc	11.83 d	181.33 bc	23.53 ab	8.66 ab
L4	137 bc	90.68 c	14.43 a	14.23 ab	24.61 b	8.97 d	30.83 c	152.30 cd	10.33 d	162.63 d	21.23 c	8.24 abcd
L5	134.67 cd	104.53 b	11.70 abc	12.43 abcd	26.68 a	11.80 a	35.63 ab	175.43 b	13.87 cd	189.30 b	22.67 bc	9.11 a
L6	139 ab	102.25 b	12.53 abc	12.17 abcd	24.38 b	9.83 bcd	29.77 c	165.00 bcd	18.97 b	183.97 bc	22.69 bc	8.63 ab
L7	138.67 ab	100.28 b	11.60 bc	11.53 cd	24.28 b	9.63 cd	31.70 c	174.60 b	19.07 b	193.67 ab	23.91 abc	7.16 cd
L8	140.33 a	110.77 a	11.90 abc	11.68 bcd	25.38 ab	10.90 abc	30.57 c	162.13 bcd	18.57 b	180.70 bc	25.00 a	7.76 bcd
L9	138.33 ab	101.22 a	12.07 abc	12.00 abcd	25.50 ab	11.53 ab	38.73 a	194.40 a	16.67 bc	211.07 a	21.90 bc	8.33 abc
L10	134 d	89.93 c	14.20 ab	13.97 abc	23.91 b	9.10 d	31.67 c	150.13 d	26.03 a	176.17 bcd	23.37 ab	7.08 d
LSD	2.97	4.42	2.75	2.57	1.78	1.70	3.61	18.09	4.35	17.54	2.12	1.215
CV%	1.27	2.58	12.60	11.77	4.15	9.71	6.40	6.39	15.07	5.62	5.41	8.74

[In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.]

DM = days to maturity, PH = plant height, NTT = number of total tillers per plant, NET = number of effective tillers per plant, LP = Length of panicle, NPBP = number of primary branches per panicle, NSBP = number of secondary branches per panicle, NFG/P = number of filled grains per panicle, NUFGP = number of unfilled grains per panicle, TSP = total number of spikelet per panicle, TSW = thousand seed weight, Y/H = yield per hectare.

Table 26: Estimates of genetic parameters in twelve important characters of ten advanced boro rice lines.

Character	δ^2P	δ^2G	PCV (%)	GCV (%)
DM	5.50	2.5	1.70	1.15
PH	85.75	79.09	9.26	8.89
NTT	3.26	.68	14.16	7.46
NET	2.90	.66	13.38	6.36
PL	1.34	.26	4.63	2.05
NPBP	1.92	.93	13.55	9.46
NSBP	11.05	6.60	10.10	7.81
TSP	346.43	133.66	10.18	6.33
NFG	270.59	159.26	9.97	7.65
NUFG	37.56	23.58	48.94	29.39
TSW	2.04	.51	6.25	3.11
Y/H	0.76	0.26	6.24	10.74

σ2p = Phenotypic variance, σ2g = Genotypic variance, DM = days to maturity, PH = plant height, NTT = number of total tillers per plant, NET = number of effective tillers per plant, LP = panicle length, NPBP = number of primary branches per panicle, NSBP = number of secondary branches per panicle, NFG/P = number of filled grains per panicle, NUFGP = number of unfilled grains per panicle, TSP = total number of spikelet per panicle, TSW = thousand seed weight, Y/H = yield per hectare

4.3.1 Days to maturity

Significant variations were observed among the lines (10.5) for days to maturity (Table 24). The highest days to maturity was taken in L8 (140 days) and the minimum days to maturity was taken in L10 (134 days), considering the selection criteria L5 (134.33) shows statistically similar performance to L10 and highest yield too. The phenotypic and genotypic variance for days to maturity was observed (5.50) and (2.5) respectively suggested that the environment had significant role in the expression of trait. The phenotypic coefficient of variation

(1.70%) was higher than genotypic coefficient of variation (1.15%) (Table 26) suggested that environment has influence on the expression of the genes controlling this trait. Similar result for this trait was also observed by Ketan and Sarkar (2014) in aman rice.

Plate 26. Photograph showing variation at 80% maturity stage

4.3.2 Plant height (cm)

The highest plant height was observed in L3 (243.9 cm) whereas the minimum plant height was observed in L2 (88.84 cm) which is near to L10 (89.93 cm) and L1 (92.25 cm) (Table 25). Phenotypic variance and genotypic variance were observed as 85.75 and 79.09 respectively. The phenotypic variance appeared to be higher than the genotypic variance suggested higher influence of environment on the expression of the genes controlling this trait. The phenotypic coefficient of variation (9.26%) and the genotypic coefficient of variation (8.89%) also indicated presence of variability among the advance lines for this trait (Table 26). The highest variation in plant height among 14 upland rice genotypes was observed by Seyoum *et al.* (2012).

4.3.3 Number of total tillers per plant

Significant variations were observed among ten lines (4.6) for number of total tillers per plant (Table 24). Among the ten lines L4 (14.43 tillers) showed the maximum number of total tillers per plant and the minimum number of total tillers per plant showed by L3 (11.30 tillers) (Table 25). Number of total tillers per plant showed phenotypic variance (3.26) is higher than genotypic variance (0.68) indicating moderate environmental influence on these characters and high difference between the phenotypic coefficient of variation (14.16%) and the genotypic coefficient of variation (7.46%) value indicating that this trait is highly influenced by the environment (Table 26). Ghosal *et al.* (2010) reported similar result for this trait in boro rice.

4.3.4 Number of effective tillers per plant

Analysis of variance (Table 24) revealed significant differences among the advance lines (4.2) for number of effective tillers per plant. The highest number of effective tillers per plant was recorded in L2 (14.30 tillers) whereas the minimum number of effective tillers per plant was recorded in L3 (11.33 tillers) (Table 25). Phenotypic variance (2.90) was high different from the genotypic variance (0.66) that indicated high environmental effect over the trait. Large difference between the phenotypic coefficient of variation (13.38%) and the genotypic coefficient of variation (6.36%) values indicated that high influence of environment on this character (Table 26). Ghosal *et al.* (2010) reported similar result for this trait in rice.

4.3.5 Panicle length (cm)

From ANOVA table (Table 24) significant difference were observed among ten advance lines (1.8) for panicle length. Among the ten lines the highest panicle length was observed in L5 (26.68 cm) which line also give the short maturity time and highest yield and the lowest panicle length was observed in L10 (23.91 cm) (Table 25). Panicle length showed less difference between phenotypic variance (1.34) and genotypic variance (0.26) indicating less environmental influence on these character and low difference between PCV (4.63%) and GCV (2.05%) value indicating the apparent variation due to lines with little low influence of environment (Table 26). Low phenotypic coefficient of variation than genotypic coefficient of variation for panicle length was reported by Kole *et al.* (2008) in rice.

4.3.6 Number of primary branches per panicle

From ANOVA table (Table 24) significant difference were observed among ten advance lines (3.78) for number of primary branches per panicle. From the mean table value, it was found that the highest number of primary branches per panicle was recorded in L5 (11.80) which is very close to L3 (11.37) while the minimum number of primary branches per panicle was recorded in L4 (8.97) (Table 25). Number of primary branches per panicle showed the low phenotypic variance (1.92) and genotypic variance (0.93) which indicated less environmental influence. The phenotypic coefficient of variability (13.55%) value was recorded for number of primary branches per panicle very close to genotypic coefficient of variability (9.46%) which indicated a less extent of the environment influences on the character. Elayaraja *et al.* (2005) found similar result.

4.3.7 Number of secondary branches per panicle

Significant variations were observed among ten advance lines of boro rice (24.26) for number of secondary branches per panicle (Table 24). Among ten lines, the highest number of secondary branches per panicle was recorded in L9 (38.73) whereas the minimum number of secondary branches per panicle was observed in L6 (29.77) (Table 25). The value of phenotypic and genotypic variance (11.05) and (6.60) respectively for number of secondary branches per panicle with high difference between them indicates high effect of environment on this character (Table 26). According to Table 26, PCV (10.10%) and GCV (7.81%) for number of secondary branches per panicle which indicate that sufficient variation exists among genotypes for this trait. Low PCV, GCV for this trait was also recorded by Kumar *et al.* (2007) in segregating generation of rice.

4.3.8 Number of filled grains per panicle

In the ten advance lines of boro rice, the number of filled grains per panicle was recorded highest in L9 (598.11) and minimum was recorded in L10 (150.13)

(Table 25). The magnitude of difference between phenotypic variances (270.59) and genotypic variances (159.26) were higher for number of filled grains per panicle suggested that large environmental influence on this character (Table 26). The high value of phenotypic (9.97%) and genotypic coefficient of variance (7.65%) respectively for this character indicated that the existence of high variation among the population with possibility of high potential for the selection. High genotypic, phenotypic variance and high GCV, PCV for this trait was also reported by Akter (2010).

4.3.9 Number of unfilled grains per panicle

Highly significant variation (66.83) among ten lines for number of unfilled grains per panicle (Table 24). The L10 showed the highest (26.03) number of unfilled grains per panicle among ten genotypes whereas the L4 showed the minimum (10.33) number of unfilled grains per panicle (Table 25). The high value of phenotypic (37.56) and genotypic (23.58) variance for number of unfilled grains per panicle with high difference between them suggests significant role of environment on the character. The difference between phenotypic (48.94%) and genotypic (29.39%) coefficient of variances were high for number of unfilled grains per panicle which indicates the existence of adequate variation among the lines (Table 26). The highest phenotypic variance, genotypic variance and phenotypic coefficient of variance, genotypic coefficient of variance was also observed by Iftekharudduaula *et al.* (2001).

4.3.10 Total number of spikelet per panicle

From the ANOVA (Table 24), it was found that total number of spikelet per panicle showed significant variations among the lines (581.1). The total number of spikelet per panicle was the maximum in L9 (211.07) and the minimum was observed in L4 (162.63) (Table 25). The phenotypic and genotypic variances for total number of spikelet per panicle were 346.43 and 133.66 respectively. The phenotypic variance was higher than the genotypic variance suggested higher influence of environment on the expression of the genes controlling this trait. The value of PCV and GCV were 10.18% and 6.33 % respectively for total number of spikelet per panicle which indicating that high variation exists among different lines (Table 26). High genotypic, phenotypic variance and high GCV, PCV for this trait was also reported by Satish *et al.* (2003).

4.3.11 Thousand seed weight (gm)

From the ANOVA (Table 24), it was found that thousand seed weight showed significant variations among the lines (3.06). Thousand seed weight was found the maximum in L8 (25.00 gm) whereas the minimum thousand seed weight was found in L9 (21.90 gm) (Table 25). The phenotypic variance (2.04) was higher than genotypic variance (0.51) indicating that environment has influence on expression of this character. The values of phenotypic coefficient of variation and genotypic coefficient of variation were 6.24% and 3.11% indicating that the line has considerable variation for this trait (Table 26). Bidhan *et al.* (2001) reported similar result for this trait.

4.3.12 Yield per hectare (t/ ha)

From the ANOVA (Table 24) revealed that the yield per hectare showed significant differences among the ten advance lines (1.27). Among the ten lines L5 showed the maximum (9.11 t/ha) yield per hectare with (statistically) shortest days to maturity (134.33) very high number of filled grain per panicle (175.43) and a smaller number of unfilled grain per panicle (13.87) trends L5 line towards its high yielding capacity. And the minimum was given yield by in L10 (7.08 t/ha) (Table 25). Yield per hectare showed phenotypic variance (1.10) is moderately higher than genotypic variance (0.79) indicating moderate environmental influence on this character. The value of phenotypic coefficient of variation (10.74%) and genotypic coefficient of variation (6.26%) indicates that this trait is influenced by the environment (Table 26). Pandey *et al.* (2010) reported low value of PCV and GCV for this trait.

CHAPTER V

SUMMARY

The present study was undertaken with ten advance boro lines of F_9 generation at the Sher-e-Bangla Agricultural University Farm, Dhaka, during November 2018 to April 2019. Seedlings were transplanted in the main field in Randomized Complete Block Design (RCBD) with three replications. The experiment was designed to characterize and study of characterization and evolution of selected advance lines on the basis of morphological, quality traits. Ten selected advance lines were evaluated for thirty-five qualitative and ten quantitative traits of morphological characters. All the lines scored exactly same for nineteen qualitative characters viz. anthocyanin coloration of leaf sheath (scored as 1), leaf color (scored as 2), penultimate leaf anthocyanin coloration of auricles and color (scored as 1), penultimate leaf ligule (scored as 9), penultimate leaf ligule shape (scored as 3), male sterility (scored as 1), microscopic observation of pollen with I2-KI solution (scored as 7), anthocyanin coloration of lemma and palea (scored as 1), anthocyanin coloration of area below lemma apex (scored as 1), anthocyanin coloration of lemma apex (scored as 1), color of stigma (scored as 1), anthocyanin coloration of nodes (scored as 1), anthocyanin coloration of internodes (scored as 1), spikelet pubescence of lemma and palea (scored as 5), spikelet color of the tip of lemma (scored as 2), awns in the spikelet (scored as 1), decorticated grain shape (scored as 9), decorticated grain bran color (scored as 1) and decorticated grain aroma (scored as 1). Such result revealed that there was no variation for these traits among the observed lines.

A wide range of variation was observed in all the lines for rest of the qualitative and all the quantitative character. The following characters such as penultimate leaf pubescence, stigma exertion, attitude of the flag leaf blade, panicle curvature, panicle attitude of branches, panicle exertion, culm diameter, culm length, panicle length, number of effective tillers per plant, time of maturity, thousand grain weight and decorticated grain length are important for selection of better boro lines. There are three types of penultimate leaf pubescence were observed in all lines among them Three lines (L1, L8 and L10) were absent or very weak type, six lines (L3, L4, L5, L6, L7 and L9) were strong hairs on the leaf blade type and only one-line L2 showed very strong type, three lines (L1, L8 and L10) were absent or very weak type, six lines (L3, L4, L5, L6, L7 and L9) were strong hairs on the leaf blade type and only one-line L2 showed very strong type. two lines (L9 and L10) were showed no or a few type stigma exertion, three lines (L4, L7 and L8) were showed low type stigma exertion, two lines (L3 and L10) were showed medium, one line (L2) were showed high type and two lines (L1 and L6) were showed very high type for exertion of stigma. There are two types of flag leaf blade seven lines (L1, L2, L3, L5, L7, L8, and L9) showed erect type flag leaf and rest three lines (L4, L6 and L10) showed intermediate or semi-erect type flag leaf. In case of panicle curvature of main axis three lines (L3, L5 and L9) were observed just exerted type, one line (L6) was observed moderately exerted type and six lines (L1, L2, L4, L7, L8 and L10) were observed well exerted type. In panicle attitude of branches all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed spreading type panicle. In case of panicle exertion three lines (L3, L5 and L9) were observed just exerted type, one line (L6) was observed moderately exerted type and six lines (L1, L2, L4, L7, L8 and L10) were observed well exerted type of the panicle exertion. Panicle length is the most yield contributing character of rice. Panicle length of observed lines ranged from Five lines (L1, L4, L6, L7 and L10) were found medium type and rest five lines were found long type. Culm length of observed lines ranged from eight medium type lines (L1, L2, L4, L5, L6, L7, L9 and L10) and two long type lines (L3 and L8) were found. In case of number of effective tillers All lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed many types of effective tillers per plant (>10 tillers per plant). Thousand grain weight character results in better agronomic performance in which six lines (L1, L2, L4, L5, L6 and L9) showed medium type of 1000 grain weight, four lines (L3, L7, L8 and L10) showed high type of 1000 grain weight. Decorticated grain length of observed in five lines (L3, L4, L5, L7 and L9) were recorded as long and rest five lines (L1, L2, L6, L8 and L10) as very long of decorticated grain length.

From variability analysis of ten advance boro lines of F_9 generation., it was observed that significant variation existing among all the lines used for most of the characters studied. The highest days to maturity was taken in L8 (140 days) and the minimum days to maturity was taken in L10 (134 days), considering the selection criteria L5 (134.33) shows statistically similar performance to L10 and highest yield too. Plant height exhibited highest in L3 (111.5 cm) and lowest in L10 (89.9 cm). Among the ten lines L4 (15 tillers) showed the maximum number of total tillers per plant and the minimum one was in L3 (11 tillers). The highest number of effective tillers per plant was recorded in L2 (14 tillers) whereas the minimum number of effective tillers per plant was recorded in L3 (11 tillers). The highest panicle length was observed in L4 (26.6 cm) and the minimum panicle length was observed in L10 (24.9 cm). The Highest number of primary branches per panicle was recorded for L5 (11.8) while the minimum number of primary branches per panicle was recorded for L10 (9.1). The highest number of secondary branches per panicle was recorded in L9 (38.73) whereas the minimum number of secondary branches per panicle was observed in L8 (30.57). The number of filled grains per panicle was recorded highest in L9 (194.40) and minimum was recorded in L10 (150.13). Line L10 (26.03) showed the highest number of unfilled grains per panicle and the L4 (10.33) showed the minimum number of unfilled grains per panicle. The total number of spikelets per panicle was maximum in L9 (211.07) and minimum was observed in L4 (162.63). Thousand seed weight was found maximum in L8 (25g) whereas the minimum thousand seed weight was found in L4 (21.23g). Among the ten Lines L5 (9.11 t/ha) showed the maximum yield per hectare and the minimum one was in L10 (7.08 t/ ha).

CHAPTER VI

CONCLUSION

Based on the results of the present study, the following conclusions may be drawn-

➢ Genotypic and phenotypic variations observed among the studied advanced boro rice lines.

➢ Yield of L5 was superior other lines.

➢ The L8 and L5 were a short duration lines with higher yield.

➢ It needs further research to find out the other qualitative characters of these two-potential advanced boro rice lines before final recommendation.

By the Consideration of morphological, quality traits, degree of variability of different important yield and yield contributing characters the most promising lines L2, L3, L4, L5, L8 and L9 were selected and would be suitable for released as high yielding boro rice variety for their short duration and high yielding characters.

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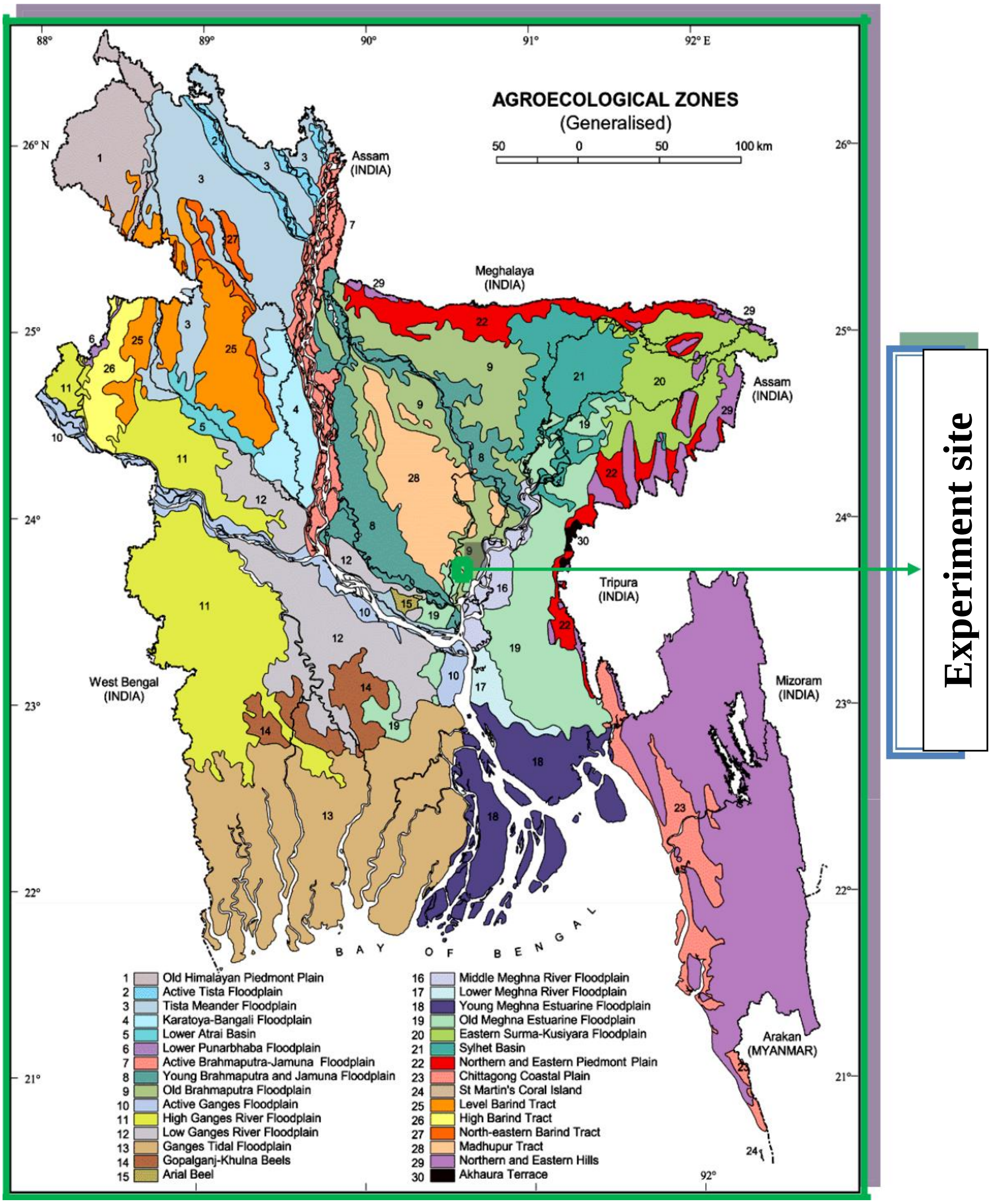
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II: Morphological characteristics of initial soil (0-15 cm depth) of the experimental site

Soil separates	Percent (%)	Methods employed
Sand	36.90	Hydrometer method (Day, 1915)
Silt	26.40	Do
Clay	36.66	Do
Texture class	Clay loam	Do

Appendix III. Monthly average Temperature, Relative Humidity and Total Rainfall of the experimental site during the period from December, 2018 to April, 2019

Month	Air temperature (ºc)		Relative humidity (%)	Rainfall (mm) (total)
	Minimum	Maximum		
December, 2018	14	26	53	6
January, 2019	15	25	54	11
February, 2019	20	30	49	8
March, 2019	23	33	45	75
April, 2019	27	35	55	53

Source: Bangladesh Meteorological Department (Climate & Weather Division), Agargoan, Dhaka -1207.

Appendix IV. Descriptors with codes for qualitative characteristics

SL. No.	Characteristics	Descriptors with Codes
1	Leaf sheath: anthocyanin Color	Absent-1, Present-9.
2	Leaf color	Pale green-1, Green-2, Dark green-3, Purple tip-4, Purple margins-5, Purple blotch-6, Purple-7.
3	Penultimate leaf Pubescence	Absent or very weak-1, Weak or only on the margins-3, Medium hairs on the medium portion of the leaf-5, Strong hairs on the leaf blade-7, Very strong-9.
4	Penultimate leaf: anthocyanin coloration of	Absent-1, Present-9.
5	auricles and collar Penultimate leaf: ligule	Absent-1, Present-9.
6	Penultimate leaf: shape of the ligule	Truncate-1, Acute-2, Split or two-cleft-3.
7	Flag leaf: attitude of the Blade	Erect (<30^0)-1, Intermediate or Semi-erect (30^0-45^0)-3, Horizontal (46^0-90^0)-5, Reflexed or descending (>90^0)-7.
8	Male sterility	Absent-1, CMS-3, TGMS-5, PGMS-7, P (T) GMS-9.
9	Microscopic observation of pollen with I2-KI solution	Completely sterile with TA pollen-1, Completely sterile with 80% TA pollen-2, Completely sterile with 50% TA pollen-3, Sterile (91-99%)-4, Partial sterile (31-70%)-5, Partial fertile (31-70%)-6, Fertile (21-30%)-7 and Fully fertile (0-20%)-8.
10	Lemma and Palea: anthocyanin coloration	Absent or very weak-1, Weak-3, Medium-5, Strong-7, Very strong-9.
11	Lemma: anthocyanin coloration of area below apex	Absent or very weak -1, Weak-3, Medium-5, Strong- 7, Very strong-9.
12	Lemma: anthocyanin coloration of apex	Absent or very weak -1, Weak-3, Medium-5, Strong- 7, Very strong-9.
13	Color of stigma	White-1, Light green-2, Yellow-3, Light purple-4, Purple-5.
14	Stigma exertion	No or a few (>5%)-1, Low (5-20%)-3, Medium (21-40%), High (41-60%)-7, Very high (>61%)-9.

Cont.

15	Stem: anthocyanin coloration of nodes	Absent-1, Present-9.
16	Stem: intensity of anthocyanin coloration of nodes	Weak-3, Medium-5, Strong-7 and Very strong-9.
17	Stem: anthocyanin coloration of internodes	Absent or very weak -1, Weak-3, Medium-5, Strong- 7, Very strong-9.
18	Panicle: curvature of main axis (i.e., recurved main axis)	Absent or very weak -1, Weak-3, Medium-5, Strong- 7.
19	Spikelet: pubescence of lemma and palea	Absent or very weak -1, Weak-3, Medium-5, Strong- 7, Very strong-9.
20	Spikelet: color of the tip of lemma	White-1, Yellowish-2, Brownish-3, Red-4, Purple-5, Black-6.
21	Spikelet: awns in the spikelet	Absent-1, Present-9.
22	Spikelet: Length of the longest awn	Very short (<2 mm)-1, Short (2-5 mm)-3, Medium (5-10 mm)-5, Long (11-20 mm)-7 and Very long (>20 mm)-9.
23	Panicle: Distribution of awns	Tip only-1, Upper half only-3 and Whole length-5.
24	Panicle: Color of awns	Yellow white-1, Brown-3, Reddish-5, Purple-7 and Black-9.
25	Panicle: attitude of branches	Erect-1, Semi-erect-3, Spreading-5.
26	Panicle: exertion	Enclosed-1, Partly exerted-3, Just exerted-5, Moderately exerted-7, Well exerted-9.
27	Leaf senescence: Penultimate leaves are observed at the time of harvest.	Late and slow (2 or more leaves retain green color at maturity)-1, Intermediate-5 and Early and fast (leaves are dead at maturity)-9.
28	Decorticated grain: shape (length-width ratio of de-hulled grain)	Round (L: W<1.5)-1, Bold (L:W=1.5-2.0)-3, Medium (L: W=2.1-2.5)-5, Medium slender (L: W=2.6-3.0)-7 and Slender (L:W>3.0)-9.
29	Decorticated grain (bran): color	White-1, Light brown-2, Variegated brown-3, Dark brown-4, Red-5, Variegated purple-6 and Purple-7.
30	Polished grain: size of white core or chalkiness (% of kernel area)	Absent or very small-1, Small (<10%)-3, Medium (11-20%)-5 and Large (11-20%)-7.
31	Decorticated grain: aroma	Absent-1, Lightly present-5 and Strongly present-9.
32	Other distinct special character (if any)	

Source: Bioversity International, IRRI and WARDA-2007. Descriptors for wild and cultivated rice (*Oryza spp*.).

Appendix V. Descriptors with codes for quantitative characteristics

SL. No.	Characteristics	Descriptors with Codes
1	Time of heading (50% of plants with heads)	Very early (< 70 days)-1, Early (70-85 days)-3, Medium (86-105 days)-5, Late (106-120 days)-7, Very late (>120 days)-9.
2	Stem: culm diameter (from 5 mother tillers in the lowest internode)	Small (<5.0 mm)-1, Medium (5.1-6.0 mm)-3, Large (6.1-7.0 mm)-5, Very Large (>7.0 mm)-7.
3	Stem length (culm length): Measure from the base of the plants to the neck of the panicles	Very short (<40 cm)-1, Short (41–60 cm)-3, Medium (61–80 cm)-5, Long (81-110 cm)-7, Very long (>110 cm)-9.
4	Panicle length: measured from the neck to the tip of the panicle of main tillers without awns	Short (<20 cm)-3, Medium (21-25 cm)-5, Long (26-30 cm)-7 and Very long (>30 cm)-9.
5	Panicle: number of the effective tillers per plant	Few (>6)-3, Medium (6-10)-5, Many (>10)-7.
6	Time of maturity	Very early (>100 days)-1, Early (101-115 days)-3, Medium (116-135 days)-5, Late (136-150 days)-7, Very late (>150 days)-9.
7	Grain: weight of 1000 fully developed grains (adjusted of 12% of moisture)	Very low (<15 gm)-1, Low (16-19 gm)-3, Medium (20-23 gm)-5, High (24-27 gm)-7, Very high (>27 gm) - 9.
8	Grain: length (without dehulling)	Very short (<6.0 mm)-1, Short (6.1-7.0 mm)-3, Medium (7.1-8.0 mm)-5, Long (8.1-9.0 mm)-7 and Very Long (>9.0 mm)-9.
9	Sterile lemma length: Measure at postharvest stage	Short (<1.5 mm)-1, Medium (1.5-2.5 mm)-3, Long (2.6-3.0 mm)-5 and Very Long (>3.0 mm)-7.
10	Decorticated grain: length (After dehulling, before milling)	Short (<5.5 mm)-1, Medium (5.6-6.5 mm)-3, Long (6.6-7.5 mm)-5 and Very Long (>7.5 mm)-7.

Source: Bioversity International, IRRI and WARDA-2007. Descriptors for wild and cultivated rice (*Oryza spp*.).

Appendix VI. Mean performance of qualitative characteristics of ten lines

Lines	LSAC	LC	PLP	PLACC	PLL	PLSL	FLAB	MS	MOP	LPAC	LACBA	LACA	CS	SE
L1	1	1	1	1	9	3	1	1	7	1	1	1	1	9
L2	1	1	9	1	9	3	1	1	7	1	1	1	1	7
L3	1	1	7	1	9	3	1	1	7	1	1	1	1	5
L4	1	1	7	1	9	3	3	1	7	1	1	1	1	3
L5	1	1	7	1	9	3	1	1	7	1	1	1	1	1
L6	1	1	7	1	9	3	3	1	7	1	1	1	1	9
L7	1	1	7	1	9	3	1	1	7	1	1	1	1	3
L8	1	1	1	1	9	3	1	1	7	1	1	1	1	3
L9	1	1	7	1	9	3	1	1	7	1	1	1	1	1
L10	1	1	1	1	9	3	3	1	7	1	1	1	1	5

LSAC: Leaf Sheath Anthocyanin Color, LC: Leaf Color, PLP: Penultimate Leaf Pubescence, PLACAC: Penultimate Leaf Anthocyanin Coloration of Auricles and Color, PLL: Penultimate Leaf Ligule, PLSL: Penultimate Leaf Shape of the Ligule, FLAB: Flag Leaf Attitude of the Blade, MS: Male Sterility, MOP: Microscopic observation of pollen with I2-KI solution, LPAC: Lemma and Palea Anthocyanin Coloration, LACBA: Lemma Anthocyanin Coloration of area below Apex, LACA: Lemma Anthocyanin Coloration of Apex, CS: Color of Stigma, SE: Stigma Exertion

(cont'd)

Appendix VII. Mean performance of qualitative characteristics of ten lines

Lines	SACN	SACI	PCMA	SPLP	SCL	SAS	PAB	PE	LS	DGS	DGC	PGC	DGA
L1	1	1	7	5	2	1	5	9	1	9	1	3	1
L2	1	1	7	3	2	1	5	9	5	9	1	1	1
L3	1	1	7	3	2	1	5	5	5	9	1	1	1
L4	1	1	7	3	2	1	5	9	5	9	1	1	1
L5	1	1	7	3	2	1	5	5	1	9	1	1	1
L6	1	1	7	3	2	1	5	7	1	9	1	1	1
L7	1	1	7	3	2	1	5	9	5	9	1	3	1
L8	1	1	7	3	2	1	5	9	1	9	1	1	1
L9	1	1	7	5	2	1	5	5	1	9	1	1	1
L10	1	1	7	3	2	1	5	9	1	9	1	1	1

SACN: Stem Anthocyanin Coloration of Nodes, SACI: Stem Anthocyanin Coloration of Internodes, PCMA: Panicle Curvature of Main Axis (i.e. recurved main axis), SPLP: Spikelet Pubescence of Lemma and Palea, SCL: Spikelet Color of the tip of Lemma, SAS: Spikelet: Awns in the Spikelet, PAB: Panicle Attitude of the Branches, PE: Panicle Exertion, LS: Leaf senescence: Penultimate leaves are observed at the time of harvest, DGS: Decorticated grain: shape (length-width ratio of de-hulled grain), DGC: Decorticated grain (bran): color, PGC: Polished grain: size of white core or chalkiness (% of kernel area), DGA: Decorticated grain: aroma.