CHARACTERIZATION AND VARIABILITY STUDY OF SOME ADVANCED BORO LINES

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CERTIFICATE

*This is to certify that the thesis entitled "**CHARACTERIZATION AND VARIABILITY STUDY OF SOME ADVANCED BORO LINES**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University (SAU), Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN GENETICS AND PLANT BREEDING,** embodies the results of a piece of bona fide research work carried out by **MD. JAHIDUL ISLAM**, Registration No. **11-04442** under my supervision and 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.

Date: June, 2017
Place: Dhaka, Bangladesh

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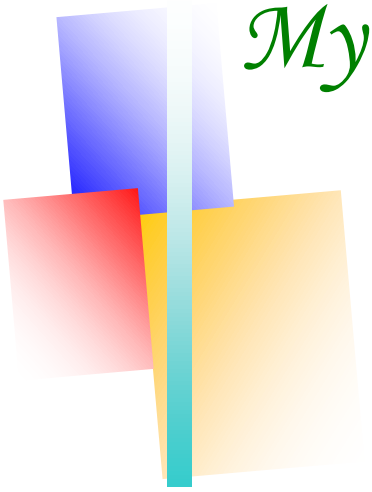
Prof. Dr. Md. Shahidur Rashid Bhuiyan
Supervisor

Dedicated To

My Respectable Parents and Teachers



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LIST OF ABREVIATIONS

Full Name	Abbreviation
Agricultural	Agril.
Agriculture	Agric.
Agro-Ecological Zone	AEZ
At the rate	@
And others	*et al.*
Bangladesh	BD
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Bangladesh Rice	BR
Bangladesh Rice Research Institute	BRRI
Biological	Biol.
International Rice Research Institute	IRRI
Biodiversity International	WARDA
Seed Certification Agency	SCA
Centimeter	cm
Days After Transplanting	DAT
Department of Agricultural Extension	DAE
Degree Celsius	^{o}C
Etcetera	etc.
Food and Agricultural Organization	FAO
Genotype	G
Genetics	Genet.
Gram	gm
High Yielding Variety	HYV
Journal	J.
Kilogram	kg
Meter	m
Ministry of Agriculture	MoA
Murate Potash	MP
Percent	%
Randomized Complete Block Design	RCBD
Sher-e-Bangla Agricultural University	SAU
Square meter	m^2
Science	*Sci.*
The fifth generation of a cross between two dissimilar homozygous parents	F_5
Ton	t
Triple Super Phosphate	TSP

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BY

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ABSTRACT

The investigation was carried out under the field conditions to characterize and variability study among the ten F_8 advanced boro rice lines and two checks (BRRI dhan 28 and BRRI dhan 29) during the period of boro season (2016-2017) at the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207.The ten advanced lines of boro rice and two checks were characterized for 31qualitative and 10 quantitative traits as a part of the release procedure. Variability study are carried out on twelve 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 characters 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 characters 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 136 days and most of the lines resulted in early maturity and lodging resistance. Most of the lines showed average number of effective tillers per plant was 12 tillers and panicle length was 22.74 cm resulted in higher yield per plant. The average thousand grain weight was 24.71 gm and average yield was 8.69 ton/ha. In case of variability study plant height, number of effective tillers, length of panicle, number of primary branches per panicle, number of secondary branches per panicle, total spikelet/panicle, no. filled grains per panicle, thousand seed weight and yield/ha showed significant variations among the lines. Comparing with the check varieties L11 (BRRI dhan 28) (8.45 t/ha) and L12 (BRRI dhan 29) (8.37 t/ha), the lines L2 (8.97 t/ha), L3 (8.79 t/ha), L4 (9.43 t/ha), L5 (9.27 t/ha), L8 (9.19 t/ha), L9 (9.61 t/ha) showed the higher yield and short duration. Thus the lines L2, L3, L4, L5, L8 and L9 would be suitable for released as high yielding boro rice variety for their short duration and high yielding characters.

CHAPTER I
INTRODUCTION

Rice is a self-pollinated cereal crop to the family of Gramineae (synonym-poaceae) under the order Cyperales and class Monocotyledon having chromosome number 2n= 24 (Hooker, 1979). The genus *Oryza* includes a total of 25 recognized species out of which 23 are wild species and two, *Oryza sativa* and *Oryza glaberrima* are cultivated (Brar and Khush, 2003). *Oryza sativa* is grown all over the world while *Oryza glaberrima* has been cultivated in West Africa for the last ~3500 years (IRRI, 2001). It can survive as a perennial crop and can produce a ratoon crop for up to 30 years but cultivated as annual crop and grown in tropical and temperate countries over a wide range of soil and climatic condition. Rice is the only cereal crop that can grow for long periods of time in standing water (IYR, 2004). About 57% of rice is grown in irrigated land, 25% in rainfed lowland, 10% in the uplands, 6% in deep water, and 2% in tidal wetlands (Chopra and Prakash, 2002). High genotypic and phenotypic diversity exists and about 1,20,000 different accessions are reported in rice globally as a consequence of varied adaptations (Das *et al*. 2013).

Rice and agriculture are still fundamental to the economic development of most of the Asian countries. Asia can be considered as 'Rice Basket' of the world, as more than 90 percent of the rice is produced and consumed in Asia. It provides 75% of the calories consumed by more than three billion asians. Approximately 11% of the world's arable land is under rice cultivation and it ranks next to wheat (Chakravarthi and Naravaneni, 2006). World paddy production area was 163.3 million hectares and production was 749.7 million tons (FAO, October, 2016). It is consumed by almost half of the world population. Rice is the staple food for at least 63% of planet inhabitants and contributes on an average 20% of apparent calorie intake of the world population (Calpe *et al.* 2007). China is in the first position as producer of rice in the world (FAOSTAT, 2016).

As a cereal grain rice is the second most important food crop next to wheat in the world but its position in Bangladesh is first in terms of providing food, income and employment. Agriculture is the largest employment sector in Bangladesh. It employs 47% of the total labor force and comprises 16% of the country's GDP (Wikipedia, 2016). Rice provides 75% of the calories and 55% of the proteins in the average daily diet of the people of Bangladesh (Bhuiyan *et al*., 2002). Rice is considered as a major crop in Bangladesh as it constitutes 91.8% of the total food grain (rice, wheat & maize) production (Anonymous, 2013). Bangladesh is the fourth largest producer of rice in the world with the annual production of 34.51 million metric tons (MMT) with the area of 11.7 million hectares (MoA 2016). Our total cultivable land is 14.85 million hectare whereas rice covered about 77 % of total cropped area (Julfiquar *et al.,* 2009). In Bangladesh total area under Aman crop has been estimated 5.6 million hectares, total area under Aus crop has been estimated at 1.02 million hectares and total area under Boro crop has been estimated 4.8 million hectares this year, (BBS, 2017). Area under Boro is the second highest which is about 39.80% of total rice land and contributes 52.07% of the total rice production (Anonymous, 2012). The major limitations of these seasons are the photosensitivity, long term dormancy and long life cycle. Now, modern high yielding and short duration varieties in boro season are essential to increase the total rice production in Bangladesh.

Almost in all major crop species, morphological and physiological descriptors are available to establish the uniqueness of a variety (Moukoumbi, *et al.*, 2011). Hence, characterization and identification of rice cultivars are crucial for the genetic varietal improvement, release and seed production programmes. Characterization of genotypes is of great importance for current and future agronomic and genetic improvement of the crop. Rice breeding strategy involves the assembling or generating variable germplasm and selection of superior genotypes from the germplasm for utilizing them as a promising variety or in hybridization programme to develop a superior variety.

A variety will not be fully accepted only for its high yielding properties until it's combined with good acceptable grain qualities that meet farmers' needs and culinary preferences. Therefore, there is need to understand available genetic resources for better quality traits since inferior grain quality of the currently high yielding varieties in the domestic market is a dominant phenomenon (Somado *et al*., 2008). Grain quality in rice is difficult to define with precision as preference for quality varies from country to country and within country from region to region and between ethnic groups even person to person. Although, some of the quality characteristics desired by the grower, miller and consumer may be the same, yet each may place different emphasis on various quality characteristics. Consumers base their concept of quality on the grain appearance, size and shape of the grain, the behavior upon cooking, the taste, tenderness and flavor of cooked rice. Thus, grain size and shape, milling and cooking characters are important criteria of rice quality, that breeder considers in developing new varieties.

Morphological characterization of advanced lines is fundamental in order to provide information for the advanced lines. Morphological characterization gives the mark of identification which distinguishes one line from other. Characterization of thes lines is not only important for utilizing the appropriate attribute based donors in breeding programmes, 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 improved advanced lines. Thus characterization of these lines would further contribute towards creating genetic database for breeding programmes strategies in the region.

For development of high yielding rice variety, the crossing between two cultivar having specific desirable characters produces numerous individuals. The superior type individuals are then sorted and cultivated as advanced lines. Characterization and variability study of these advanced lines is the prerequisite to develop new rice variety. A breeding program was initiated in 2008 to develop short duration high yielding boro varieties. After a continuous process of selection ten F_8 advanced lines were selected based on their maturity period and yielding ability. The ten F_8 advanced lines obtained through boro × 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 (10) advanced lines.

OBJECTIVES:

1. To characterize advanced boro lines as per descriptors used for rice.
2. To study genetic variability of some important quantitative characters among the advanced lines.
3. To select short duration and high yielding boro materials for further trial.

CHAPTER II

REVIEW OF LITERATURE

Rice has wide adaptability to different environmental conditions, as it is evident from its worldwide distribution. Yield of rice variety is determined by the morphological parameters such as 50% flowering, days to 80% maturity, plant height (cm), total no. of tiller per plant, no. of effective tiller/plant, panicle length (cm) per plant, no. of primary branches per plant, no of secondary branches per plant, total no. of spikelet per panicle, no. of filled grain of main tiller, no. of unfilled grain of main tiller, yield per plant (gm), thousand grain weight (gm) and yield (ton/hectare). The identification of suitable combinations of genotypes in comparison to the best parent varieties for yield and some important yield contributing characters are essential tool for a successful assessment. 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 present study has aimed to assess the performance of genotypes as compared to the check varieties. The literature relevant to the present investigation entitled "Characterization and variability study of some advanced boro lines" through morphological traits and variability has been reviewed in this section.

2.1 Characterization

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

Miller *et al*. (1991) studied that rice tillering is a major determinant for panicle production and as a consequence affects total yield. The high tillering capacity is considered as a desirable trait in rice production, since number of tillers per plant is closely related to number of panicles per plant. To some extent, yield potential of a rice variety may be characterized by tillering capacity. On the other hand, it was reported that the plants with more tillers showed a greater inconsistency in mobilizing assimilates and nutrients among tillers. Moreover, grain quality could be also affected by tillering ability due to different grain developmental characteristics. It has been well documented that either excessive or insufficient tillering is unfavorable for high yield.

Shehata *et al.* (2009) carried out an investigation to evaluate the morphological variation among Egyptian Jasmine and its 10 M_5 derived mutants. The results showed that all tested genotypes including Egyptian Jasmine and its new derived mutants were significantly varied in their growth duration, yield and yield components except number of tillers. Interestingly, derived mutants significantly headed earlier than Egyptian Jasmine. The results clearly showed the existence of considerable amount of variation at the morphological level and demonstrate the significance of mutation breeding in enhancing genetic variability in the breeding programs.

Rangare *et al.* (2012) evaluated forty exotic and Indian rice germplasm including one local check for their efficiency with respect to eleven yield and yield contributing characters from Kharif, 2009 under normal conditions. Associated studies have indicated that for an improvement in grain yield, the intensive selection should be positive for biological yield per plant, number of fertile tillers per plant, number of spikelet per panicle, test weight, panicle length and days to maturity as these traits showed significantly strong positive association with grain yield, but days to 50% flowering, days to initial flowering, harvest index and plant height through had positively non-significant association with grain yield.

Nabeela *et al.* (2004) evaluated a total of 124 landrace genotypes of rice were for seven quantitative and eight qualitative characters. A significant amount of genetic variation was displayed for most of the traits. The coefficient of variation was more than 10% for all the characters with the exception of grain length. Compared with the modern cultivars the landrace genotypes were on average delayed in heading and maturity but had lower values for panicle and grain length. Days to heading was positively correlated with maturity (r=0.833) and grain length (r=0.452). Plant height showed positive and significant correlation with panicle length (r=0.452), indicating the importance of plant height in improving panicle length. Seven accessions with the best performance for individual character were identified.

Sarhadi *et al.* (2008) worked with the most important agronomic attributes and aroma of 26 cultivars from Afghanistan, Iran, and Uzbekistan, and controls from Japan, Thailand and India were characterized. Diversity for some traits of agronomic importance, such as plant height was detected among countries, e.g. Afghan cultivars classified as tall, and Iranian and Uzbek intermediate and short, respectively. Differentiations of panicle, grain, leaf, basal internodes, and culm dimension among rice cultivars, indicating the source of rice diversity in Central Asia. According to the results, 6 of 10, 2 of 7, and 0 of 6 of Afghan, Iranian, and Uzbek rice cultivars were scored as aromatic, respectively. Therefore. Afghan cultivars are a good source of aromatic rice germplasm for Central Asia.

Mohapatra *et al*. (1993) evaluated 13 agro-morphological characters of 34 mutant lines for the magnitude of genetic divergence using Mahalanobis's D^2 statistics. The population was grouped into seven clusters. Plant height (24.6%) and 1000 grains weight (18.3%) contributed considerably, accounting for 43% of total divergence.

Ingale *et al.* (2007) conducted an experiment to study the effect of seedling age on 50% flowering of parental lines of sahyadri rice hybrid. The experiment was formulated to assess the effect of seedling age at transplanting on 50% flowering of A, B, and R lines of sahyadri rice hybrid. The 50% flowering was delayed in both younger and older aged seedlings than the recommended age of seedling (25 days old) at transplanting by approximately half the number of days by which the seedlings are younger and older than the recommended age.

Sadeghi (2011) observed positive significant association of grain yield with grains per panicle, days to maturity, number of productive tillers and days to flowering.

Dutta *et al.* (2013) studied 68 genotypes for twelve agronomical important characters to estimate variability and genetic parameters. Considering genetic parameters, high genotypic and phenotypic coefficient of variations, high heritability (broad sense) and genetic advance as percentage of mean were observed viz. tillers per plant, days to flowering, harvest index, spikelet per panicle, spikelet density, panicle per plant and spikelet yield. Thus, these characters were under the influence of additive gene action and a satisfactory selection program.

Satheesh Kumar *et al.* (2012) estimated correlation in fifty three genotypes of rice for fifteen characters. It revealed grain yield per plant exhibited high significant and positive genotypic correlation with number of productive tillers per plant, filled grains per panicle and total number of grains.

Akhtar *et al.* (2011) studied the genotypic and phenotypic correlation for yield contributing characters in ten rice genotypes. Paddy yield had strong genetic correlation with number of grains per panicle, days to maturity and 1000 grain weight. Paddy yield had significant positive correlation with number of grains per panicle and 1000 grain weight.

Kumar *et al.* (2009) carried out an experiment to study the selection criteria for selecting high yielding genotypes in two different early segregating F_2 and F_3 populations by estimating heritability and genetic correlation between yield and its main economic traits in their subsequent F_3 and F_4 generations of two crosses in rice. The heritability estimates were high for spikelet/main panicle and 100 grain weight, whereas it was medium to low for grain yield and low for panicles/plant.

Akter *et al.* (2007) evaluated thirty advanced breeding lines of deep-water rice during T. aman season with a view to finding out variability and genetic association for grain yield and its component characters. The highest genetic variability was obtained in filled grains/panicle followed by plant height. Panicles/plant, filled grains/panicle and grain yield had genetic coefficient of variation and heritability in broad sense coupled with high genetic advances in percentage of mean. Panicle length, panicles/plant, plant height, filled grains/panicle and harvest index showed significant positive association with grain yield.

Hien *et al.* (2007) conducted an investigation to determine the extent of diversity and relationships among 36 aromatic rice cultivars collected from Asia. Characterization for 22 morphological characters with 101 morphometric descriptors was carried out. High and comparative levels of phenotypic variation using phenotypic frequency distribution and Shannon-Weaver diversity index were found between Countries of origin. Most traits were polymorphic except to ligule color, grain size, grain shape, culm strength, plant height and secondary branching contributed the highest mean diversity indices.

Sankar *et al.* (2006) conducted an experiment with 34 rice genotypes and high heritability as well as genetic advance was obtained for productive tillers per plant.

Xu-Zheng Jin *et al*. (2007) evaluated Forty-six rice cultivars and lines in Liaoning, Jilin and Heilongjiang provinces of China in 2004 were used to study particle characteristics and their relationship with yield and quality traits in Shenyang city, Gongzhuling city and Jiamusi city. The panicle length in Liaoning was 2 cm shorter than that in Jilin and Heilongjiang. Grain density, number of primary branches and number of grains in the primary branch in Liaoning were much higher than those in Jilin and Heilongjiang.

Singh *et al.* (2006) evaluated thirty two genotypes of rice for seven traits to estimate genetic variability and interrelationship among them. There was found a wide range variation for all the characters. Highest genotypic and phenotypic coefficients of variations were recorded for grain yield. High heritability and high genetic advance for height suggested the predominance of additive gene action for this trait.

Hossain *et al.* (2005) conducted a study in order to investigate the relationship between grain yield with the morphological parameters of five local and three modern aromatic rice varieties. Among the aromatic rice varieties the highest grain yield was obtained from BRRI dhan 34 which identically followed by Kataribhog. The highest number of effective tillers/hill was observed in BRRI dhan 37. Badshabhog, Chinigura, BRRI dhan 38 and the lowest fertile tillers per hill was obtained from Kalijira which was statistically similar to Kataribhog. The highest number of grains per panicle was found in BRRI dhan 34 and that was the lowest in BRRI dhan 38. Maximum 1000- grains weight was observed in BRRI dhan 38. In respect of yield BRRI dhan 34 and Kataribhog are suitable for Dinajpur region in Bangladesh during T. aman season.

Shashidhar *et al.* (2005) reported positive association of spikelet yield with plant height, number of productive tillers hill-1, dry matter plant-1 and harvest index at15 phenotypic and genotypic level.

Madhavilatha *et al.* (2005) evaluated Fifty four elite rice genotypes for their variability with regards to grain yield, yield components (plant height, number of effective tillers per plant, panicle length. number of grains per panicle, fertility percentage, days to 50% flowering, days to maturity and harvest index) and quality parameters (hulling recovery, kernel length (L), breadth (B), L/B ratio and elongation ratio, volume expansion ratio and 1000 grains weight). Estimation of heritability and genetic advance were also obtained for the above traits.

Sharief *et al.* (2005) observed morphological characters of four rice cultivars. The varieties were identified through their flag leaf area, angle of the flag leaf, plant height, time of heading, lemma and palea pubescence, culm diameter, number of secondary branches per to particle, number of grains per panicle, panicle density, particle weight, presence of awn, number of tillers, filled grain yield. 1000-grains weight, seed width and grain color.

Rana and Bhat, (2004) conducted an 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.

Zaman *et al.* (2004) evaluated 8 agro-morphological characters of 20 modern rice varieties for the magnitude of genetic divergence using Mahalanobis's D2 statistics and reported that days to flowering and plant height contributed consistently to total divergence.

Chand *et al.* (2004) studied nineteen genotypes of aman paddy (*Oryza sativa)* emanating from different sources different sources for spikelet yield and their components during kharif. Heritability and genetic advance as percentage of mean were high for 1000 spikelet weight.

Souresh *et al.* (2004) studied the genetic diversity of quantitative and qualitative traits of 36 lines and cultivars of rice using 17 traits including grain yield, number of particles per plant, number of filled grains per panicle, 1000-grainsweight, leaf length, leaf width, leaf area, plant height, culm length, amylose content of the grain, gel consistency, panicle weight, grain length, grain width, grain shape, days to 50% flowering and maturity.

Mishra *et al.* (2003) evaluated 16 rice cultivars and their 72 F_1 hybrids for genetic diversity and grouped in twelve clusters using Mahalanobis's D^2 statistics. The values revealed that plant height, ear bearing tillers per plant, panicle length, 1000 grain weight, hulling and milling percentage, biological yield, harvest index, kernel length after cooking, gelatinization temperature and grain yield were the main factors for differentiation.

Shiv and Mani (2003) evaluated genetic divergence in elite genotypes of Basmati rice and found that plant height contributed maximum towards genetic divergence (52.2) followed by days to 50% flowering and grain yield /plant.

Itani (2002) evaluated the agronomic characteristics of aromatic rice collected from all over Japan, 71 randomly selected cultivars were cultivated along with 21 foreign aromatic cultivars from 7 countries and l8 Japanese non-aromatic cultivars. In addition, 44 Japanese aromatic cultivars and 6 old and I2 new non-aromatic cultivars were examined for their leaf characteristics. The local Japanese aromatic cultivars had a greater height, fewer and larger panicles, greater straw weight, lower yield, less tolerance to lodging and more awns than the new cultivars.

Roy *et al.* (2002) evaluated 50 rice cultivars for genetic diversity and responded that plant height, tiller numbers, panicle length, 1000 grains weight. 1000 kernel weight, filled grains/panicle and kernel-grain ratio contributed most towards divergence.

Basher (2002) studied genetic divergence among 36 genotypes by using D^2 statistics for 15 characters related to yield and its contributing characters. The genotypes were grouped into six clusters. The results revealed that the harvest index had the highest contribution followed by tillers per plant, panicle length, 1000 grains weight, filled grains per panicle, days to maturity and leaf photosynthetic rate towards genetic divergence.

Jiang *et al.* (2000) observed the importance of number of tillers/plant influencing yield. Productive tillers/hill showed significant positive correlations with correlations with grain yield (Reddy and Kumar, 1996).

Li and Yuan (1998) reported the parental genotype divergence had a relatively low impact on heterosis for panicle number and 1000 grain weight. Plant height, panicle per plant, grain per panicle and 1000 grain weight increase the yield in modern varieties (Saha Ray *et al.*, 1993).

Vijaya kumar *et al.* (1997) found that hybrids out yielded than their check varieties when their days to 50% flowering were similar or more than their respective restorers. They concluded that superior hybrids could be early by comparing their tiller number, plant height and days to 50% flowering with those of their respective restorers.

Ghosh and Hossain (1988) reported that effective tillers/plant, number of grains/panicle and grain weight as the major contributory characters for grain yield it had positive correlations with number of productive tillers/plant.

Sarma *et al.* (1990) studied the grain characteristics of 13 traditional aromatic rice varieties of Assam and reported wide variation in grain length (566 - 994 mm), breadth (180 - 296 mm), L/B ratio (2.44) and 1000 grains weight (8.44 - 25.48 gm). Obviously, some of the collections had extra ordinarily high grain length and could be used as donors in breeding programs.

Reddy and Kumar (1996). stated that the broad sense heritability is the relative magnitude of genotypic and phenotypic variance for the traits and it gives an idea of the total variation accounted to genotypic effect. Ghose and Ghatge (1960) also stated that tiller number, panicle length contributed to yield with grain yield

Kumar *et al*. (2016) characterized 64 aromatic rice germplasm for 35 agromorphological and quality traits and all 64 rice germplasm were found to be distinct on the basis of thirty one agro-morphological and quality traits. Accessions having short stem length, very long panicle length, more number of panicle per plant, and extra-long slender grain may be used as potential donor in hybridization programmes.

2.2 Variability

An experiment was carried out by Lingaiah *et al.* (2014) to evaluate the variability parameters for quantitative traits in 33 rice genotypes. Analysis of variance revealed the presence of significant differences among genotypes for all traits studied. The genotypic and phenotypic coefficients of variations were moderate to high for no. of grains/panicle, test weight and yield. High heritability coupled with high genetic advance as percent of mean was observed for days to 80% maturity, no. of grains/panicle, test weight and yield indicating the role of additive gene in controlling these characters.

Akhter *et al.* (2010) examined the genetic variability, character association and path analysis of 52 exotic rice genotypes for reproductive traits. There was recorded significant genetic variability among genotypes. The highest genotypic variance and phenotypic variance were recorded in case of pollen sterility and filled grains per panicle. High heritability and genetic advance were recorded for pollen sterility. The selection could be based on filled grains per panicle only according to genetic parameters, association and path analysis.

Kumar *et al.* (2014) conducted experiment with 40 genotypes of rice**.** Analysis of variance revealed significant difference among 40 rice genotypes for all characters indicating the existence of variability. High GCV and PCV were observed for grain yield per plant and biological yield per plant.

Ghosal *et al*. (2010) evaluated eighteen advanced breeding lines for yield and yield contributing characters to observe their variability, associations and direct and indirect effect on yield during Boro season, 2009. All the tested characters showed significant variation. Effective tillers/m2 and spikelet sterility (%) had high genotypic variance, high heritability, high genetic advance and high genotypic coefficient of variation. Effective tillers/m2, panicle length (cm), thousand grain weight (g) and growth duration (days) showed significant positive association with grain yield.

Ketan and Sarkara (2014) to observed significant variability for nineteen quantitative characters in an experiment conducted with 26 indigenous aman rice cultivars. The magnitude of PCV was observed higher than the corresponding GCV for all the characters. High heritability was observed days to 50 per cent flowering, plant height, 1000 grain weight, panicle length, florets number per panicle, kernel length and kernel L/B ratio. Number of grains per panicle recorded the highest genetic advance followed by floret number per panicle, plant height and number of secondary branches. High heritability in conjunction with high genetic advance was registered for plant height, days to 50 per cent flowering and number of secondary branches. High heritability with low genetic advance was observed for panicle length, panicle weight, kernel length and kernel L/B ratio.

Gupta *et al.* (1999) studied genetic variability for grain yield and its component traits in 95 genotypes of rice and found high heritability and low genetic advance for days to flowering.

Elayaraja *et al.* (2005) observed high heritability associated with moderate to high genetic advance as a percent of mean for number of productive tillers, panicle length, number of grains per panicle, 100 grain weight and grain yield per plant in M2 generation.

Seyoum *et al*. (2012) conducted a field experiments using 14 rice genotypes to estimate the genetic variability, heritability of grain yield and yield contributing traits in upland rice. Days to 50% flowering, plant height, grains per panicle, spikelets per panicle, thousand grains weight and grain yield showed relatively high GCV and PCV estimates. High heritability was obtained for plant height (92.17%), followed by 50% flowering (90.16%), thousand grains weight (83.17%), days to 85% maturity (82.45%), panicle length (79.25%) and spikelet per panicle (60.25%) which indicates high heritable portion of variation. High to medium estimates of heritability and genetic advance were obtained for plant height, days to 50% flowering, panicles per plant, spikelets per panicle, grains per panicle and thousand grains weight, indicating the roles of additive gene action and a good scope of selection using their phenotypic performance.

Kole *et al*. (2008) studied variability for twelve morphological characters were studied on 18 morphologically distinct mutants in M4 generation along with their two mother genotypes (IET 14142 and IET 14143), which were developed from Tulaipanja, an aromatic non-basmati rice cultivar of West Bengal. Genotypic and phenotypic coefficients of variation were high for flag leaf angle and panicle number; moderate for grain number per panicle, straw weight, harvest index and grain yield per plant; and low for days to flower, plant height, panicle length, spikelet number, spikelet fertility (%) and test weight. High heritability accompanied by high to moderate genetic advance for flag leaf angle, panicle number, grain number, straw weight and grain yield indicated the predominance of additive gene action for the expression of these characters.

Kumar *et al.* (2007) conducted a study to estimate of genotypic and phenotypic coefficient of variation, heritability and genetic advance as percent of mean in the F2 and F3 segregating populations of six crosses of rice for six yield and yield component characters. The F2 populations of the cross P1 P3 showed high PCV, GCV coupled with high heritability estimates and high genetic advance as percentage of mean for number of filled grains per panicle, 100-grain weight, biomass per plant and grain yield per plant. Similarly, the F3 population of the cross P2 P1 exhibited high genetic parameters for number of productive tillers per plant and grain yield per plant. These populations could be subjected to simple pure line selection to improve grain yield per plant.

Bidhan *et al*. (2001) evaluated 25 medium duration genotypes for eight traits and observed high phenotypic and genotypic variances for grain yield, followed by number of filled grains per panicle. They recorded heritability which ranged from 50% (grain yield per hill) to 90% (grain breadth). Genetic advance as percent of mean was highest for number of filled grains per panicle (70.34), followed by grain yield (68.72). Number of filled grains per panicle, 1000-grain weight, grain length and breadth exhibited less environmental effect and high heritability coupled with moderate to high genetic advance.

Iftekharuddaula *et al*. (2001) studied twenty-four modern rice varieties of irrigated ecosystem with a view to finding out variability and genetic association for grain yield and its component characters. All the characters tested were showed significant variation among the varieties. The highest genetic variability was obtained in spikelets/panicle and grains/panicle. High heritability together with high genetic advance in percentage of mean was observed in plant height, 1000-grain weight, grains/panicle and spikelets/panicle.

Yadav (2001) evaluated genetic variability for yield and its components in 124 rain fed landraces of rice for genetic variability and found significant variability for number of tillers/plant.

Satish *et al.* (2003) genetic variability, heritability and genetic advance were studied in 200 scented rice genotypes including one non-scented check, Ratna for grain yield and its nine attributing characters. High GCV and PCV values spikelets/panicle, number of grains/ panicle and grain yield/plant. High heritability along with high genetic advance was observed for number of spikelets/panicle, number of grains/panicle, grain yield/plant followed by other characters. Emphasis should be given on these characters while selecting scented rice varieties to improve grain yield.

Ullah *et al.* (2011) estimated the genetic variability, interrelationship and cause effect analysis of ten traditional fine rice cultivars for morph-physiological character. There was found significant variation with all the characters. The higher genotype coefficient of variation (GCV) was found for grains per panicle followed by grain yield per plant. 1000-grain weight and panicles per plant. High heritability was observed for all the tested characters except harvest index. High heritability with high genetic advance in percentage of means was found for grains per panicle, grain yield per plant and 1000-grain weight indicating role of additive gene action.

Pandey *et al.* (2010) observed significant genetic variability among twenty two indigenous rice genotypes for yield and quality contributing traits. There was found sufficient amount of variability in the study materials and scope of selection. Phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for various characters. However the difference between GCV and PCV was minimum for most of the characters studied indicating less degree of environmental influence on manifestation of these characters. High heritability coupled with high genetic advance were recorded. The number of spikelet per panicle showed the major role of additive gene action in the inheritance of these characters and characters could be improved by selection in segregating generation and could serve as an effective selection tools during breeding program for crop improvement.

Bisne *et al.* (2009) estimated the genetic parameters for yield and yield contributing characters in rice from a trial with four CMS lines, eight testers and thirty two hybrids for thirteen characters related to yield. High genotype and phenotype coefficients of variations were recorded in harvest index, total number of filled spikelets per panicle. 1000-grain weight and spikelet fertility percentage. High heritability with moderate genetic advance was showed by harvest index, total number of chaffy spikelets per panicle, grain yield per plant and total number of filled spikelets per panicle and selection may be effective for these characters.

kumar *et al*. (2004) conducted by an experiment to examine the genetic diversity among 50 restorers. They indicated that all the restorer lines were grouped into eight clusters indicating that the high level of variability exist among the lines. The biological yield contributed height (32%) towards divergence followed by panicle length (28.7%), plant height (27%).

Mishra *et al.* (2002) evaluated 16 rice cultivars and 72171 progenies and found that the phenotypic coefficient of variation was higher than the genotypic coefficient of variation (GCV) for number of fertile spikelets/panicle, high heritability coupled with high genetic advance was observed for number of fertile spikelets/panicle.

Seetharamaiah *et al.* (2001) evaluated sixty-four rice genotypes for floral and morphological traits. Maximum heritability coupled with high-expected genetic advance in case of panicle exertion and plant height was observed, indicating additive gene action in governing these traits.

CHAPTER III

MATERIALS AND METHODS

The details of different populations used and methodology followed during the experimental period are described in this chapter as follows:

Experimental treatments and sources of plant populations:

3.1 Experimental Site

The experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during November 2016 to April 2017. 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 VI.

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 VII.

3.3 Planting Materials (Lines)

Ten (10) advanced lines with two check varieties (BRRI dhan 28 and BRRI dhan 29) were used as experimental materials in the study. Descriptions of the lines are given in Table l.

Table 1. List of materials used for the experiment

Lines	Pedigree	Source
L1	BRRI dhan 29 × BRRI dhan 36 $S_5P_3P_1S_1$	GEPB, SAU
L2	BRRI dhan 29 × BRRI dhan 36 $S_5P_2P_4S_3$	GEPB, SAU
L3	BRRI dhan 28 × BRRI dhan 29 $S_2P_4P_3S_3$	GEPB, SAU
L4	BRRI dhan 28 × BRRI dhan 29 $S_2P_4P_3S_2$	GEPB, SAU
L5	BRRI dhan 29 × BRRI dhan 36 $S_5P_2P_4S_6$	GEPB, SAU
L6	BRRI dhan 28 × BRRI dhan 29 $S_2P_4P_3S_4$	GEPB, SAU
L7	BRRI dhan 28 × BRRI dhan 36 $S_7P_8S_2$	GEPB, SAU
L8	BRRI dhan 29 × BRRI dhan 36 $S_5P_2P_4S_5$	GEPB, SAU
L9	BRRI dhan 29 × BRRI dhan 36 $S_2P_2P_4S_6$	GEPB, SAU
L10	BRRI dhan 29 × BRRI dhan 36 $S_5P_2P_7S_2$	GEPB, SAU
L11	BRRI dhan 28	BRRI
L12	BRRI dhan 29	BRRI

L=Lines

Plate 1. Seed Soaking for germination

Plate 2. Processing of sprouting

Plate 3. Seed sowing in seedbed

Plate 4. Transplanting in main field

Plate 5. Field view of the experimental plot

3.4 Design and Layout

The experiment was laid out in randomized complete block design (RCBD). The field was divided into three blocks; the blocks were sub-divided into 12 plots (lines) where genotypes were randomly assigned. The experimental field size was 27 m x 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 and 2 check varieties were distributed to each plot within each block randomly.

3.5 Collection of Seed

The seeds of ten boro lines were collected from germplasm center of Sher-e-Bangla Agricultural University (SAU). Two check varieties (BRRI dhan 28 and BRRI dhan 29) were collected from Bangladesh Rice Research Institute (BRRI).

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 with repeated ploughing following by laddering. Sprouted seeds were sown separately in the previously wet seedbed on 19 November, 2016. 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 recommended by BRRI.

3.9 Application of Fertilizers

The fertilizers N, P, K, S and B in the form of urea, TSP, MP, Gypsum and Borax respectively were applied.The entire amount of TSP, MP, Gypsum, Zinc Sulphate and Borax were applied during final land preparation. Urea was applied in three equal installments during ploughing, vegetative stage and before flowering. 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 (%)		
		Basal	1st installment	2nd installment
Urea	127	33.33	33.33	33.33
TSP	52	100	--	--
MP	60	100	--	--
Gypsum	0	0	--	--
Borax	0	0	--	--

Source: BRRI (2015), Jodebpur, Gazipur.

3.10 Transplanting of Seedling

Healthy seedlings of 33 days old were transplanted on 22 December 2016 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 discourge 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 were 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

After basal dose, 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 @ l kg per square meter 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 plots. 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 II & III. The observations for characterization were recorded under field condition as follows.

3.12.1 Qualitative Traits Evaluation Methods

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 II & III) 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 was 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 per 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 per 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 was 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 per follows.

Absent-1 and Present-9.

3.12.1.5 Penultimate Leaf: Ligule

Data was 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 per 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.

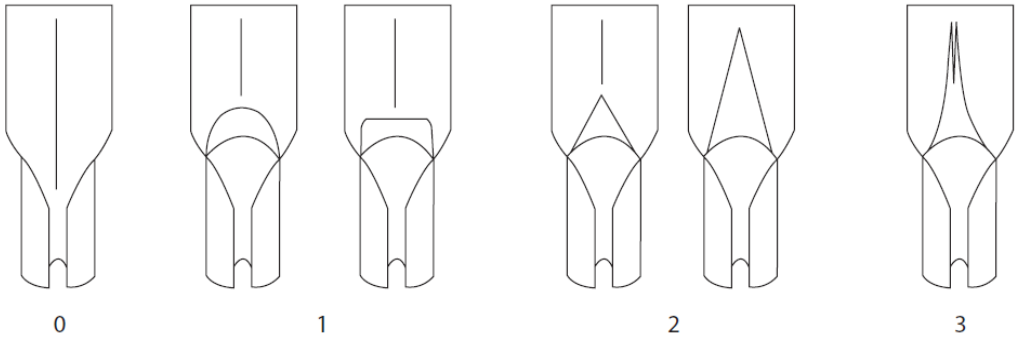

Figure 1. Ligule shape.

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 ($<30^0$)-1,

Intermediate or Semi-erect (30^0-45^0)-3,

Horizontal (46^0-90^0)-5 and

Reflexed or descending ($>90^0$)-7.

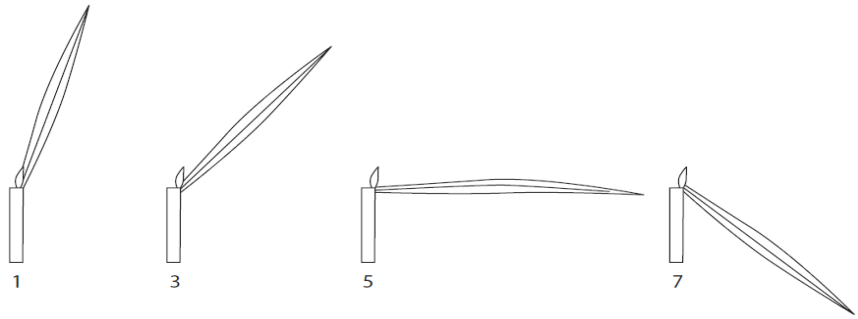

Figure 2. Flag leaf attitude

3.12.1.8 Male Sterility

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

Absent-1,

CMS-3, TGMS-5,

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

3.12.1.9 Microscopic Observation of Pollen with I_2-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 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.

3.12.1.10 Lemma and Palea: Anthocyanin coloration

Data was 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 per 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 was 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 per 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 was 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 per follows.

Absent or very weak-1,

Weak-3, Medium-5,

Strong-7 and Very strong-9.

3.12.1.13 Color of Stigma

Data was 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 per follows.

White -1, Light green-2,

Yellow-3, Light purple-4 and

Purple-5.

3.12.1.14 Stigma Exertion

Data was 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 per 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 was 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 per follows.

Absent-1 and

Present-9.

3.12.1.16 Stem: Intensity of anthocyanin coloration of nodes

Data was 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 per follows.

Weak-3, Medium-5,

Strong-7 and Very strong-9.

3.12.1.17 Stem: Anthocyanin coloration of internodes

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

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.

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 per 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 per 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.

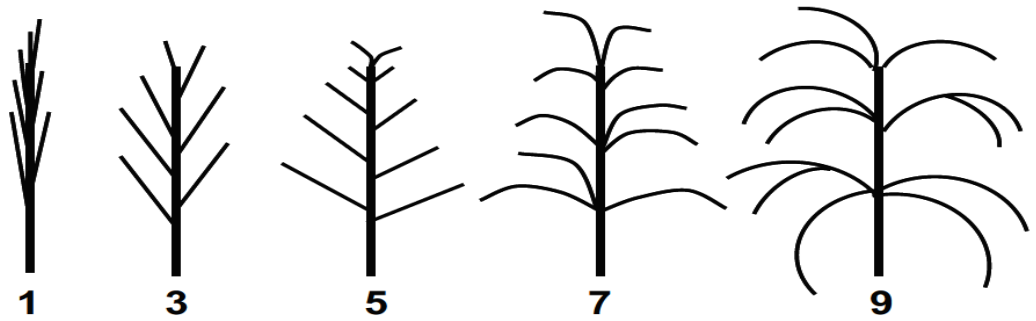

Figure 3. Attitude of panicle branches

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 per follows.

Enclosed-1, Partly exerted-3

Just exerted-5, Moderately exerted-7 and

Well exerted-9.

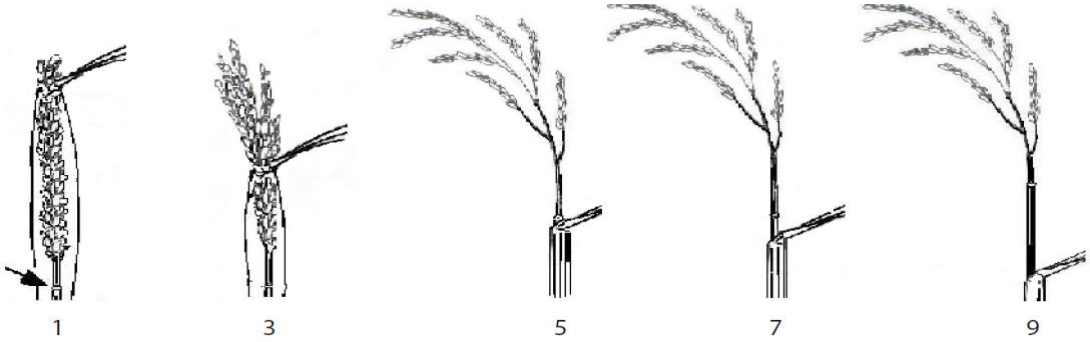

Figure 4. Panicle exertion.

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

Data was collected at the time of harvest and the observed 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.

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

Data was collected at the time of harvest and the observed 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.

3.12.1.29 Decorticated Grain (bran): Color

Data was collected at the time of harvest and the observed 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.

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

Data was collected at the time of harvest and the observed 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 and

Large (11-20%)-7.

3.12.1.31 Decorticated Grain: Aroma

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

Absent-1,

Lightly present-5 and

Strongly present-9.

3.12.1.32 Other Distinct Special Character (if any)

3.12.2 Quantitative Traits Evaluation Methods

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 (<5.0 mm)-1, Medium (5.1-6.0 mm)-3,

Large (6.1-7.0 mm)-5 and Very Large (>7.0 mm)-7

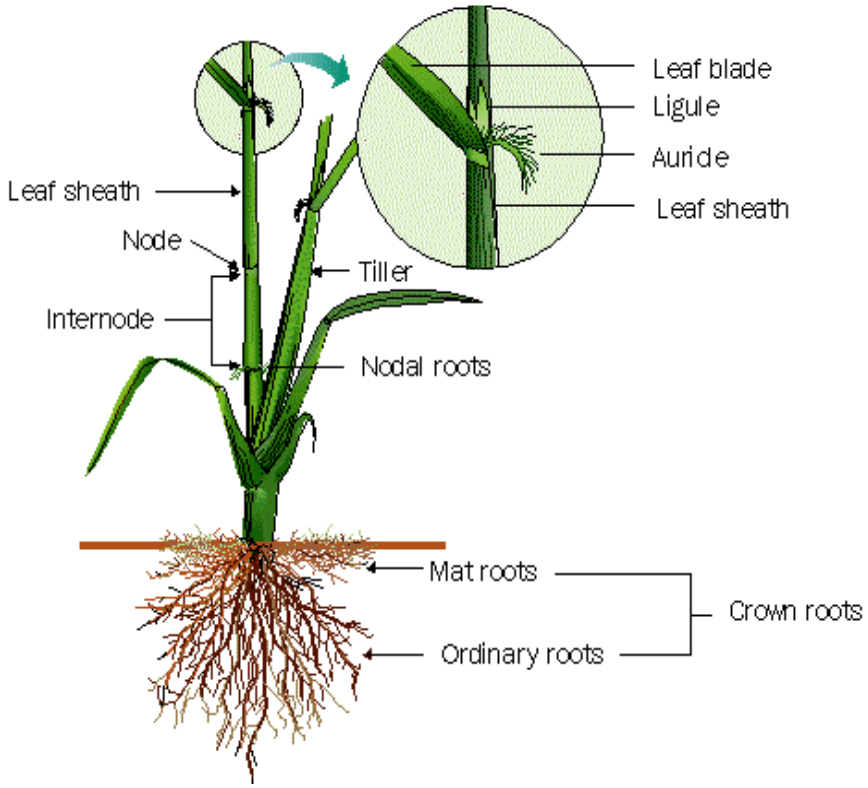

Figure 5. Morphology of a rice plant (vegetative stage)

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 (<40 cm)-1,

Short (41–60 cm)-3,

Medium (61–80 cm)-5,

Long (81-110 cm)-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 was 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 (21-25 cm)-5,

Long (26-30 cm)-7 and Very long (>30 cm)-9.

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 (<15 gm)-1, Low (16-19 gm)-3,

Medium (20-23 gm)-5, High (24-27 gm)-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 genotypes were measured and the mean value was recorded. The lines were classified as per the guided descriptors.

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.

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 genotypes were measured and the mean value was recorded. The lines were classified as per the guided descriptors.

Short (<1.5 mm)-1,

Medium (1.5-2.5 mm)-3,

Long (2.6-3.0 mm)-5 and

Very Long (>3.0 mm)-7.

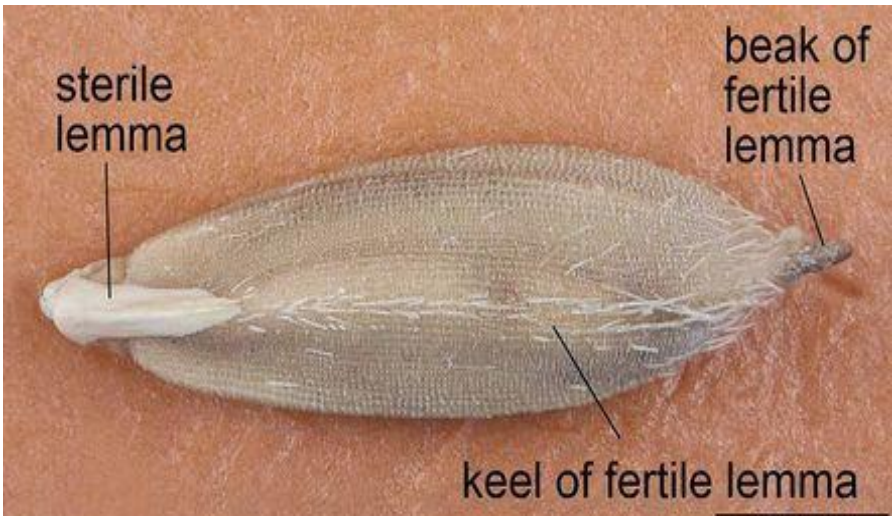

Figure 6. Rice grain with sterile lemma.

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 lines were measured and the mean value was recorded. The lines were classified as per the guided descriptors.

Short (<5.5 mm)-1,

Medium (5.6-6.5 mm)-3,

Long (6.6-7.5 mm)-5 and

Very Long (>7.5 mm)-7.

3.12.3 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 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 panicle 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 tiller per plant was recorded as the number of panicle 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 cleaned seeds 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.

3.12.4.1 Estimation of variability

Collected data on the ten lines were used to statistical analysis for each character, analysis of variance (ANOVA), mean, range were calculated by using MSTATC 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).

i. Analysis of variance (ANOVA)

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

Source of variation	d.f	M.S.S.	EMSS	F-Ratio
Replication (r)	r-1	M1		M1/M3
Genotypes (g)	g- 1	M2	$\delta_e^2 + \delta_g^2$	M2/M3
Error(e)	(r-1)(g-1)	M3	δ_e^2	

Where.

r = Number of replications

g = Number of genotypes

d.f. = degree of freedom

M.S.S. = Mean sum of square

EMSS = Expected values of M.S.S.

ii. Estimation of variance components

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

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

Where, MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error and

r = Number of replication

b. Phenotypic variance, $\boldsymbol{\delta_p^2 = \delta_g^2 + \delta_e^2}$

Where, δ_g^2 = Genotypic variance,

δ_e^2 = 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) (%) $= \frac{\sqrt{\delta_g^2}}{\bar{x}}$ x 100

Where,

δ_g^2 = genotypic varirnce

$\bar{x}$ = population mean

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

Where,

δ_p^2 = 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 characterizing and evaluating ten advanced lines of boro rice as per the guided descriptors developed by BIOVERSITY INTERNATIONAL, IRRI and WARDA-2007. Thirty one qualitative and ten quantitative characters were observed. For the estimation of variability twelve yield and yield contributing characters were also observed. Results have been compiled in tabular form according to descriptors and described by the following ways:

- Qualitative Characteristics
- Quantitative Characteristics
- Variability among the twelve lines of rice

4.1 Characterization based on qualitative Characteristics

4.1.1 Leaf Sheath: Anthocyanin color

On the basis of leaf sheath anthocyanin coloration the observed lines were categorized as absent-1 and present-2 according to guided descriptors as per follows. But no coloration was found in this investigation (Table 3). A pictorial view of leaf sheath anthocyanin color is present in Plate 6.

4.1.2 Leaf Color

Based on leaf color 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 per follows. All lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12) showed green color. Pale green, dark green, purple tip, purple margins, purple blotch and purple green type leaf were not found in any lines (Table 4). Pictorial view of leaf color is present in Plate 7.

Table 3. Categorization and grouping based on leaf sheath anthocyanin color

Types	Code	Lines
Absent	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Present	2	Nil

Table 4. Categorization and grouping based on leaf color

Types	Code	Lines
Pale green	1	Nil
Green	2	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Dark Green	3	Nil
Purple tip	4	Nil
Purple margins	5	Nil
Purple blotch	6	Nil
Purple	7	Nil

4.1.3 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. Seven lines (L1, L2, L5, L8, L9, L10 and L11) were absent or very weak type, four lines (L3, L4, L6 and L7) were medium hairs on the lower portion of the leaf type and only one line L12 showed very strong type. Weak or only on the margins and Strong hairs on the leaf blade were not found in any lines (Table 5). A pictorial view of penultimate leaf pubescence is present in Plate 8 and 9.

4.1.4 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 twelve lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12) absent penultimate leaf anthocyanin coloration of auricles and collar that means there was no significant difference among the lines (Table 6). A pictorial view of anthocyanin coloration of auricles and color of penultimate leaf is present in Plate 10.

4.1.5 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, L10, L11 and L12) presence ligule of the penultimate leaf that means there was no significant difference among the lines (Table 7).

Table 5. Categorization and grouping based on penultimate leaf pubescence

Types	Code	Lines
Absent or very weak	1	L1, L2, L5, L8, L9, L10 and L11
Weak or only on the margins	3	Nil
Medium hairs on the lower portion of the leaf	5	L3, L4, L6 and L7
Strong hairs on the leaf blade	7	Nil
Very strong	9	L12

Table 6. Categorization and grouping based on penultimate leaf anthocyanin coloration of auricles and collar

Types	Code	Lines
Absent	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Present	2	Nil

Table 7. Categorization and grouping based on penultimate leaf ligule

Types	Code	Lines
Absent	1	Nil
Present	9	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12

Plate 6. Leaf sheath anthocyanin color

Plate 7. Green color leaf

Plate 8. Penultimate leaf pubescence (Absent or very weak)

Plate 9. Penultimate leaf pubescence (Medium hairs on the lower portion)

4.1.6 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, L10, L11 and L12) were two-cleft type that means there was no significant difference among the lines in this character (Table 8). 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 11.

4.1.7 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 ($<30^0$)-1, intermediate or semi-erect (30^0-45^0)-3, horizontal (46^0-90^0)-5, reflexed or descending ($>90^0$)-7 type. Here eleven lines (L1, L2, L4, L5, L6, L7, L8, L9, L10, L11 and L12) showed erect type flag leaf and rest one lines (L3) showed intermediate or semi-erect type flag leaf (Table 9). Pictorial view of attitude of the blade of flag leaf is present in Plate 12 and 13.

4.1.8 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, L10, L11 and L12) had absence of male sterility that means there was no significant difference among the lines (Table 10).

Table 8. Categorization and grouping based on ligule shape of penultimate leaf

Types	Code	Lines
Truncate	1	Nil
Acute to acuminate	2	Nil
Two-Cleft	3	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12

Table 9. Categorization and grouping based on attitude of the blade of flag leaf

Types	Code	Lines
Erect	1	L1, L2, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Semi-erect	3	L3
Horizontal	5	Nil
Reflexed or descending	7	Nil

Table 10. Categorization and grouping based on male sterility

Types	Code	Lines
Absent	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
CMS	3	Nil
TGMS	5	Nil
PGMS	7	Nil
P(T) GMS	9	Nil

Plate 10. Absence of anthocyanin coloration of auricle and collar

Plate 11. Split or two-cleft type of ligule

4.1.9 Microscopic observation of Pollen with I_2-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, L10, L11 and L12) were fertile that means there was no significant difference among the lines (Table 11).

4.1.10 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, L10, L11 and L12) were observed no anthocyanin coloration of lemma and palea or very weak anthocyanin coloration of lemma and palea for seed coat color (Table 12).

4.1.11 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, L10, L11 and L12) 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 13).

Table 11. Categorization and grouping based on microscopic observation of pollen with I_2-KI solution

Types	Code	Lines
Completely sterile with TA pollen	1	Nil
Completely sterile with 80% TA pollen	2	Nil
Completely sterile with 50% TA pollen	3	Nil
Sterile (91-99%)	4	Nil
Partial sterile (31-70%)	5	Nil
Partial fertile (31-70%)	6	Nil
Fertile (21-30%)	7	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Fully fertile (0-20%)	8	Nil

Table 12. Categorization and grouping based on lemma and palea anthocyanin color

Types	Code	Lines
Absent or very weak	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Weak	3	Nil
Medium	5	Nil
Strong	7	Nil
Very strong	9	Nil

Table 13. Categorization and grouping based on anthocyanin coloration of area below lemma apex

Types	Code	Lines
Absent or very weak	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Weak	3	Nil
Medium	5	Nil
Strong	7	Nil
Very strong	9	Nil

4.1.12 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, L10, L11 and L12) 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 14).

4.1.13 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 green-2, yellow-3, light purple-4 and purple-5. All the twelve lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12) 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 15).

4.1.14 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 five lines (L6, L8, L9, L11 and L12) were showed low type stigma exertion, four lines (L3, L5, L7 and L10) were showed medium type stigma exertion and rest three lines (L1, L2 and L4) were showed high type for exertion of stigma (Table 16). A pictorial view of stigma exertion of rice is present in Plate 14 and 15.

Table 14. Categorization and grouping based on anthocyanin coloration of lemma apex

Types	Code	Lines
Absent or very weak	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Weak	3	Nil
Medium	5	Nil
Strong	7	Nil
Very strong	9	Nil

Table 15. Categorization and grouping based on color of stigma

Types	Code	Lines
White	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Light green	2	Nil
Yellow	3	Nil
Light purple	4	Nil
Purple	5	Nil

Table 16. Categorization and grouping based on stigma exertion

Types	Code	Lines
No or a few (>5%)	1	Nil
Low (5-20%)	3	L6, L8, L9, L11 and L12
Medium (21-40%)	5	L3, L5, L7 and L10
High (41-60%)	7	L1, L2 and L4
Very high (>61%)	9	Nil

Plate 12. Erect type attitude of the flag leaf blade

Plate 13. Semi-erect type attitude of the flag leaf blade

Plate 14. Low type stigma exertion of rice

Plate 15. High type stigma exertion of rice

4.1.15 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 twelve lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12) were observed no anthocyanin coloration of nodes that means there was no significant difference among the lines (Table 17). A pictorial view of anthocyanin coloration of nodes is present in plate 16.

4.1.16 Stem: Intensity of anthocyanin coloration of nodes

Data were collected after flowering to near maturity stage on stem anthocyanin coloration of nodes and the 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, L10, L11 and L12) 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.

4.1.17 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 twelve lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12) were observed no anthocyanin coloration of internodes that means there was no significant difference among the lines (Table 18). A pictorial view of anthocyanin coloration of internodes is present in Plate 17.

Table 17. Categorization and grouping based on stem anthocyanin coloration of nodes

Types	Code	Lines
Absent	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Present	9	Nil

Table 18. Categorization and grouping based on stem anthocyanin coloration of internodes

Types	Code	Lines
Absent	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Present	9	Nil

4.1.18 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 seven lines (L3, L4, L8, L9, L10, L11 and L12) were observed medium type and five lines (L1, L2, L5, L6 and L7) were observed strong type of panicle curvature of main axis (Table 19). Pictorial view of panicle curvature of main axis is present in Plate 18.

4.1.19 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 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 twelve lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12) were observed medium type pubescence of lemma and palea that means there was no significant difference among the lines (Table 20). Pictorial view of pubescence of lemma and palea is present in Plate19.

4.1.20 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 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 twelve lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12) 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 21).

Table 19. Categorization and grouping based on panicle curvature of main axis (i.e. recurrent main axis)

Types	Code	Lines
Absent or very weak (upright)	1	Nil
Weak (semi-upright)	3	Nil
Medium (slightly drooping)	5	L3, L4, L8, L9, L10, L11 and L12
Strong (strongly dropping)	7	L1, L2, L5, L6 and L7

Table 20. Categorization and grouping based on pubescence of lemma and palea of the spikelet

Types	Code	Lines
Absent or very weak	1	Nil
Weak	3	Nil
Medium	5	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Strong	7	Nil
Very strong	9	Nil

Table 21. Categorization and grouping based on color of the tip of lemma of the spikelet

Types	Code	Lines
White	1	Nil
Yellowish	2	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Brownish	3	Nil
Red	4	Nil
Purple	5	Nil
Black	6	Nil

Plate 16. Absence of anthocyanin coloration of nodes

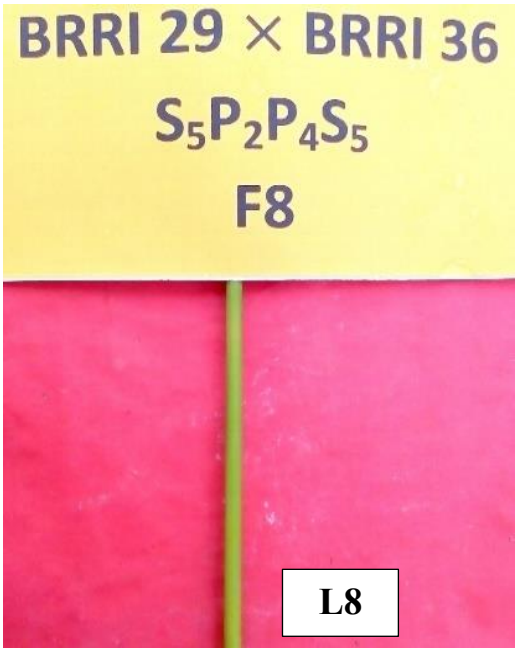

Plate 17. Absence of anthocyanin coloration of internodes

Plate 18. Medium Panicle curvature of main axis

Plate 19. Medium pubescence of lemma and palea

4.1.21 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, L10, L11 and L12) were showed no awns in the spikelet (Table 22).

4.1.22 Spikelet: Length of the longest awn

It was observed at maturity stage and normally a character of wild species of rice and grouped as per descriptors such as 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. In this case there was no awns in the spikelet present in all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12). So length of the longest awn in the spikelet of all lines was not present.

4.1.23 Panicle: Distribution of awns

It was observed at flowering to maturity stage and normally a character of wild species of rice and grouped as 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, L10, L11 and L12). So distribution of awns in the panicle of all lines was not present.

4.1.24 Panicle: Color of awns

It was observed at flowering to maturity stage and normally a character of wild species of rice and grouped as 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, L10, L11 and L12). So color of awns in the panicle of all lines was not present.

4.1.25 Panicle: Attitude of branches

The compactness of the panicle was classified according to its mode of branching, angle of primary branches, and spikelet density in three groups as erect (compact panicle)-1, semi-erect (semi-compact panicle)-3 and spreading (open panicle)-5 type panicle where eleven lines (L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12) showed semi-erect type and rest one line (L1) showed spreading type panicle. Erect typed panicles were not found among the lines (Table 23)**.** Pictorial view of attitude of branches of panicle is present in Plate 20 and 21.

4.1.26 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 two lines (L1 and L2) were observed just exerted type, six lines (L3, L4, L5, L6, L9 and L12) were observed moderately exerted type and four lines (L7, L8, L10 and L11) were observed well exerted type of the panicle exertion. Enclosed type of panicle exertion was not found (Table 24).

Table 22. Categorization and grouping based on awns in the spikelet

Types	Code	Lines
Absent	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Present	9	Nil

Table 23. Categorization and grouping based on panicle attitude of branches

Types	Code	Lines
Erect	1	Nil
Semi-erect	3	L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Spreading	5	L1

Table 24. Categorization and grouping based on panicle exertion

Types	Code	Lines
Enclosed	1	Nil
Partly exerted	3	Nil
Just exerted	5	L1 and L2
Moderately exerted	7	L3, L4, L5, L6, L9 and L12
Well exerted	9	L7, L8, L10 and L11

4.1.27 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 seven lines (L1, L5, L6, L8, L9, L10 and L12) showed late and slow (2 or more leaves retain green color at maturity) level and rest five lines (L2, L3, L4, L7 and L11) 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 25)**.**

4.1.28 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, L10, L11 and L12) showed slender type grain shape. Round, bold, medium and medium slender type decorticated grain were not found among the lines (Table 26)**.** Pictorial view of decorticated grain shape is present in plate 22.

4.1.29 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, L10, L11 and L12) showed white colored decorticated grain (bran). Light brown, variegated brown, dark brown, red, variegated purple and purple decorticated grain (bran) coloration were not found among the lines (Table 27)**.** Pictorial view of decorticated grain (bran) color is present in Plate 23.

Table 25. Categorization and 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, L10 and L12
Intermediate	5	L2, L3, L4, L7 and L11
Early and fast (leaves are dead at maturity)	9	Nil

Table 26. Categorization and grouping based on decorticated grain shape

Types	Code	Lines
Round	1	Nil
Bold	3	Nil
Medium	5	Nil
Medium slender	7	Nil
Slender	9	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12

Table 27. Categorization and grouping based on decorticated grain (bran) color

Types	Code	Lines
White	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Light brown	2	Nil
Variegated brown	3	Nil
Dark brown	4	Nil
Red	5	Nil
Variegated purple	6	Nil
Purple	7	Nil

Plate 20. Semi-erect type panicle attitude

Plate 21. Spreading type panicle attitude

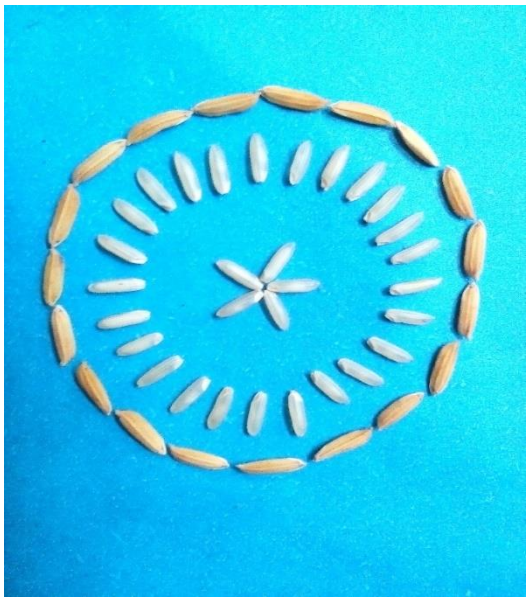

Plate 22. Decorticated grain shape

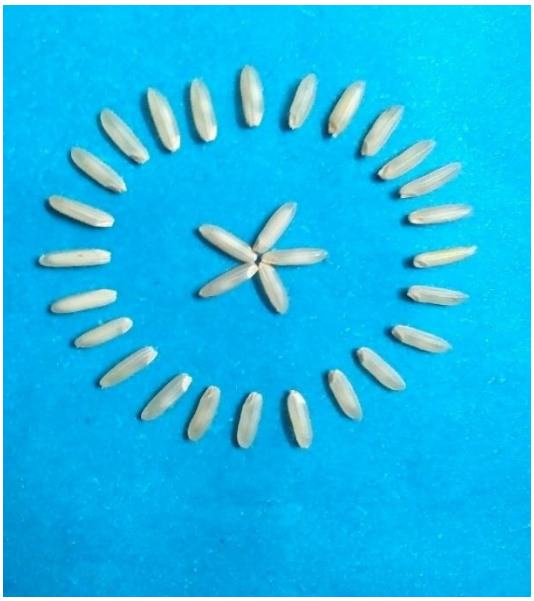

Plate 23. White colored decorticated grain

4.1.30 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 and large (11-20%)-7 where ten lines (L2, L3, L4, L5, L6, L8, L9, L10, L11 and L12) 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 28)**.**

4.1.31 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 twelve lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12) were observed no aroma present in decorticated grain that means there was no significant difference among the lines (Table 29).

4.1.32 Other Distinct Special Character (if any)

In this experiment there were no distinct special characters found.

Table 28. Categorization and 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, L10, L11 and L12
Small (<10%)	3	L1 and L7
Medium (11-20%)	5	Nil
Large (11-20%)	7	Nil

Table 29. Categorization and grouping based on aroma of decorticated grain

Types	Code	Lines
Absent	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12
Lightly present	5	Nil
Strongly present	9	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, boro lines were classified into five groups viz. very early (<70 days), early (70-85 days), medium (86-105 days), late (106-120 days) and very late (>120 days). Six lines (L3, L4, L5, L7, L8 and L9) showed medium and six lines (L1, L2, L6, L10, L11 and L12) showed late but no lines were found as very early, early and very late type for 50% heading formation (Table 30). A pictorial view of time of heading (50% of the plants with heads) is present in plate 24.

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 5.10 mm to 6.90 mm with a mean value of 6.11 mm (Appendix-V). On the basis of this character, the lines were categorized into four groups as small (<5.0 mm), medium (5.1-6.0 mm), large (6.1-7.0 mm) and very large (>7.0 mm) as the guided descriptors where there was no small and very large type lines. On the other hand, five medium type lines (L2, L4, L5, L7 and L9) and seven large type lines (L1, L3, L6, L8, L10, L11 and L12) were found (Table 31). From the figure-7 we also can distinguish different groups of observed lines based on culm diameter where lines and culm diameter has been presented horizontal and vertical axis respectively.

Table 30. Categorization and grouping based on time of heading

Groups	Scale (Days)	Code	Lines
Very early	<70	1	Nil
Early	70-85	3	Nil
Medium	86-105	5	L3, L4, L5, L7, L8 and L9
Late	106-120	7	L1, L2, L6, L10, L11 and L12
Very Late	>120	9	Nil
Range	(L4) 102 days - (L12) 115 days		
Average	106 days		

Table 31. Categorization and grouping based on culm diameter

Groups	Scale	Code	Lines
Small	<5.0 mm	1	Nil
Medium	5.1-6.0 mm	3	L2, L4, L5, L7 and L9
Large	6.1-7.0 mm	5	L1, L3, L6, L8, L10, L11 and L12
Very Large	>7.0 mm	7	Nil
Range	(L2) 5.10 mm - (L12) 6.90 mm		
Average	6.11 mm		

Plate 24. Time of heading (50% of plants with heads).

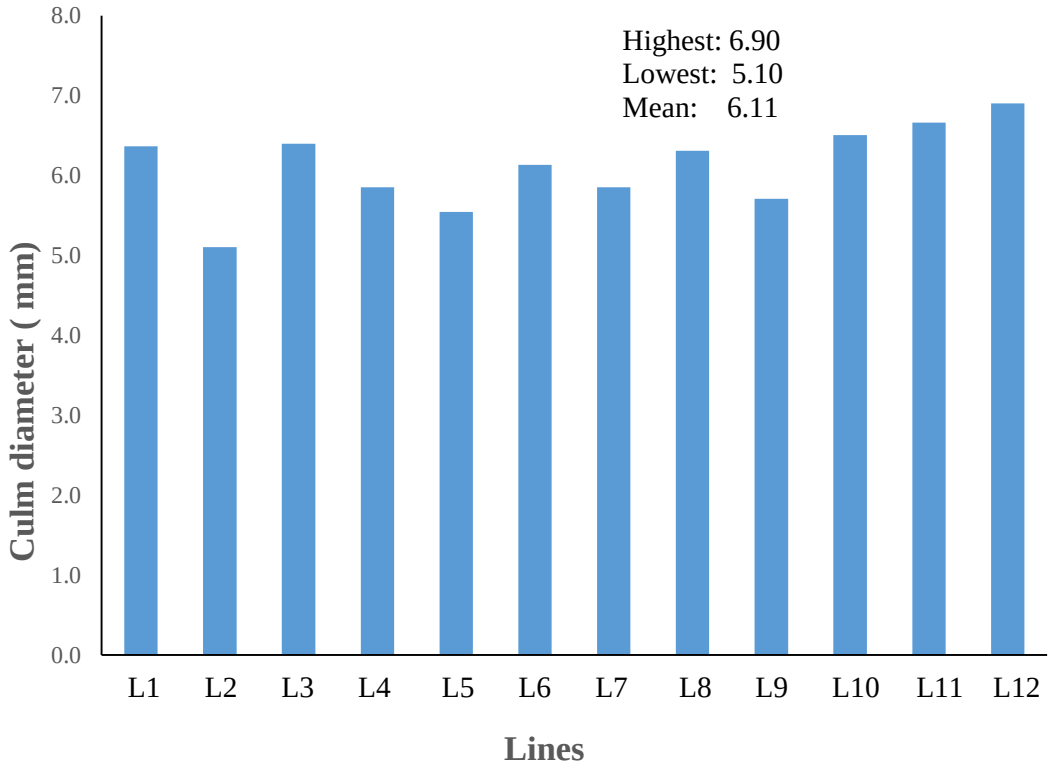

Figure 7. Grouping of observed lines based on culm diameter.

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 54.94 cm to 75.67 cm with a mean value of 63.95 cm (Appendix-V). On the basis of this character, the lines were categorized into five groups as very short (<40 cm), short (41–60 cm), medium (61–80 cm), long (81-110 cm) and very long (>110 cm) as the guided descriptors where there were no very short type, long and very long type lines. On the other hand, four short type lines (L2, L5, L8 and L9) and eight medium type lines (L1, L3, L4, L6, L7, L10, L11 and L12) were found (Table 32).

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 21.79 cm to 24.75 cm with a mean value of 22.74 cm (Appendix-V). 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 (<20 cm), medium (21-25 cm), long (26-30 cm) and very long (>30 cm) as the guided descriptors where there were no short type, long type and very long type lines. All the twelve lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, and L12) were found medium type (Table 33). From the figure-8 we also can distinguish different groups of observed lines based on panicle length where lines and panicle length has been presented horizontal and vertical axis respectively.

Table 32. Categorization and grouping based on culm length

Groups	Scale	Code	Lines
Very short	<40 cm	1	Nil
Short	41-60 cm	3	L2, L5, L8 and L9
Medium	61-80 cm	5	L1, L3, L4, L6, L7, L10, L11 and L12
Long	81-110cm	7	Nil
Very long	>110 cm	9	Nil
Range	(L8) 54.94 cm - (L7) 75.67 cm		
Average	63.94 cm		

Table 33. Categorization and grouping based on panicle length

Groups	Scale	Code	Lines
Short	<20 cm	1	Nil
Medium	21-25 cm	5	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, and L12
Long	26-30 cm	7	Nil
Very long	>30 cm	9	Nil
Range	(L10) 21.79 cm - (L1) 24.75 cm		
Average	22.74 cm		

4.2.5 Panicle: Number of the effective tillers per plant

The number of effective tillers per plant of the observed lines ranged from 9 tillers to 15 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 was no lines showed few type of effective tillers per plant. On the other hand only two lines (L4 and L6) showed medium type of effective tillers per plant and rest lines (L1, L2, L3, L5, L7, L8, L9, L10, L11, and L12) showed many type of effective tillers per plant (Table 34).

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 133 days to146 days with a mean value of 136 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). There was no lines showed very early, early and very late maturity of plant. On the other hand eight lines (L1, L3, L4, L5, L7, L8, L9 and L10) showed medium type maturity of plants and rest four lines (L2, L6, L11 and L12) showed late type maturity of plants (Table 35). This grouping based on time of maturity is also shown in bar graph for more easy perception by the following figure-9 where lines has been shown horizontal axis and time of maturity along vertical axis.

Table 34. 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	L4 and L6
many	>10 tillers	7	L1, L2, L3, L5, L7, L8, L9, L10, L11 and L12
Range	(L4) 9 tillers - (L9) 15 tillers		
Average	12 tillers		

Table 35. Categorization and grouping based on time of maturity

Groups	Scale (Days)	Code	Lines
Very early	>100	1	Nil
Early	101-115	3	Nil
Medium	116-135	5	L1, L3, L4, L5, L7, L8, L9 and L10
Late	136-150	7	L2, L6, L11 and L12
Very Late	>150	9	Nil
Range	(L3) 133 days - (L12) 146 days		
Average	136 days		

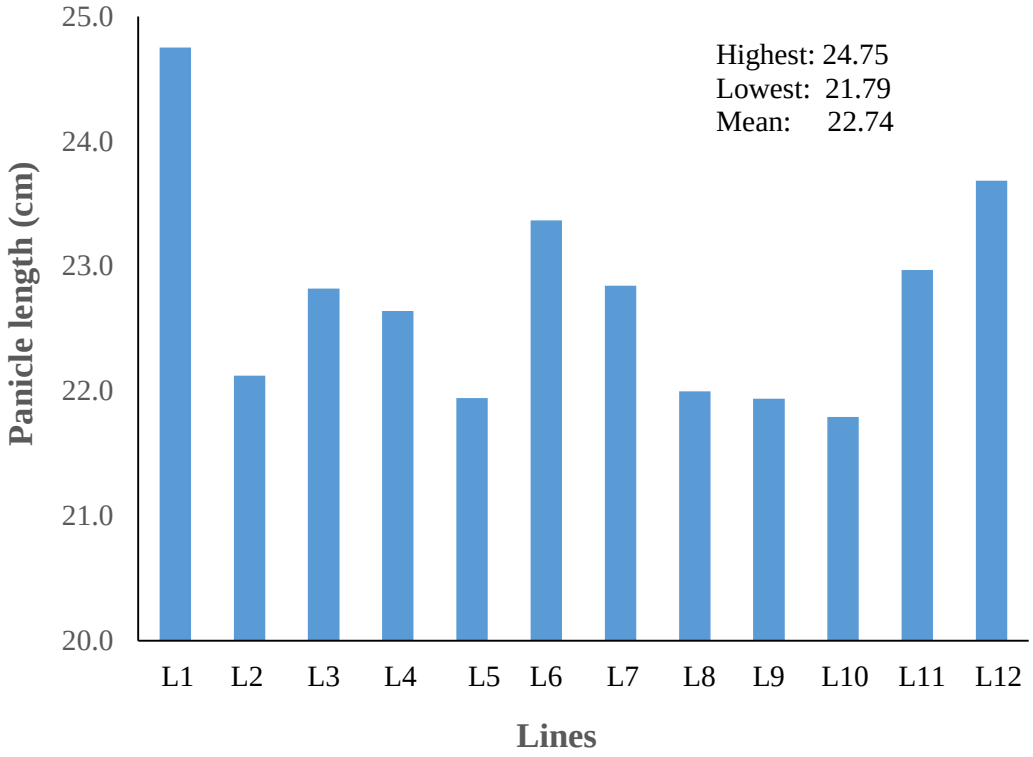

Figure 8. Grouping based on panicle length.

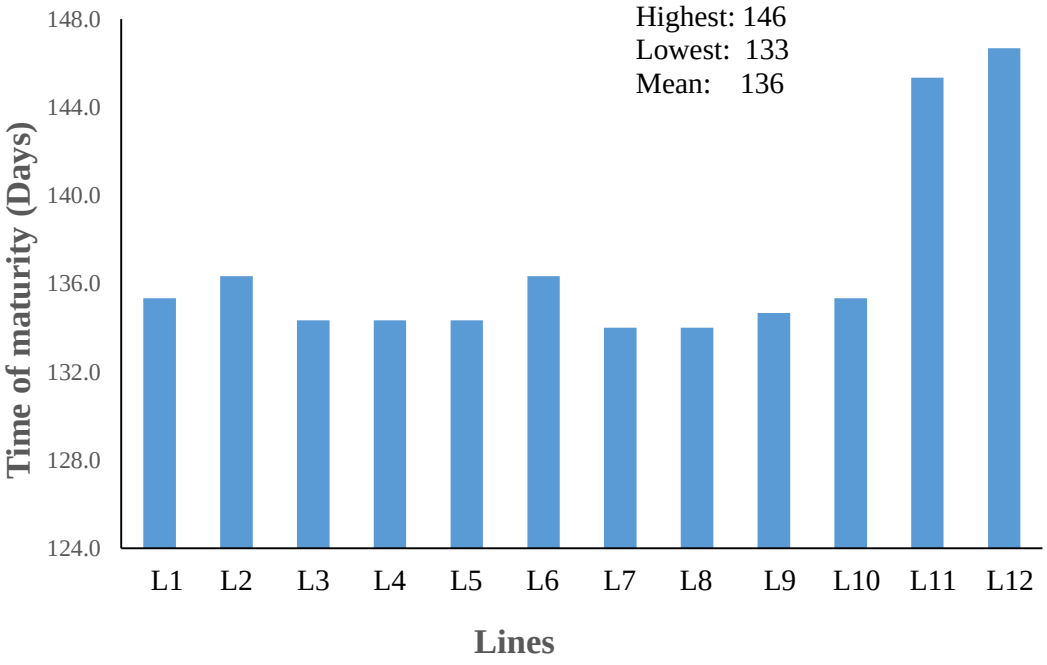

Figure 9. Grouping based on time of maturity.

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

Thousand grain weight of the observed lines ranged from 21.46 gm to 27.73 gm with a mean value of 24.71 gm (Appendix-V) and considering this character, the lines were grouped as four types such as very low (<l5 gm), low (l6-19 gm), medium (20-23 gm), high (24-27 gm) and very high (>27 gm). In this situation, there was no lines showed very low and low type of 1000 grain weight. On the other hand four lines (L1, L7, L9 and L10) showed medium type of 1000 grain weight, seven lines (L2, L4, L5, L6, L8, L11 and L12) showed high type of 1000 grain weight and rest one lines (L3) showed very high type of 1000 grain weight (Table 36).

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 lines were measured and the mean value was recorded. Grain length of the lines ranged from 8.29 mm to 10.36 mm with a mean value of 9.12 mm (Appendix-V). On the basis of grain length, the observed lines were grouped as very short (<6.0 mm), short (6.1-7.0 mm), medium (7.1-8.0 mm), long (8.1-9.0 mm) and very Long (>9.0 mm). Four lines (L3, L4, L7 and L12) were recorded as long and rest eight lines (L1, L2, L5, L6, L8, L9, L10 and L11) as very long (Table 37). No lines were found as very short, short and medium type. Pictorial view of grain length is present in Plate 25 and 26.

Table 36. Categorization and grouping based on thousand grain weight (adjusted of 12% of moisture)

Groups	Scale	Code	Lines
Very Low	<15 gm	1	Nil
Low	16-19 gm	3	Nil
Medium	20-23 gm	5	L1, L7, L9 and L10
High	24-27 gm	7	L2, L4, L5, L6, L8, L11 and L12
Very High	>27 gm	9	L3
Range	(L7) 21.46 gm - (L3) 27.73 gm		
Average	24.71 gm		

Table 37. 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, L7 and L12
Very Long	>9.0 mm	9	L1, L2, L5, L6, L8, L9, L10 and L11
Range	(L4) 8.29 mm - (L1) 10.36 mm		
Average	9.12 mm		

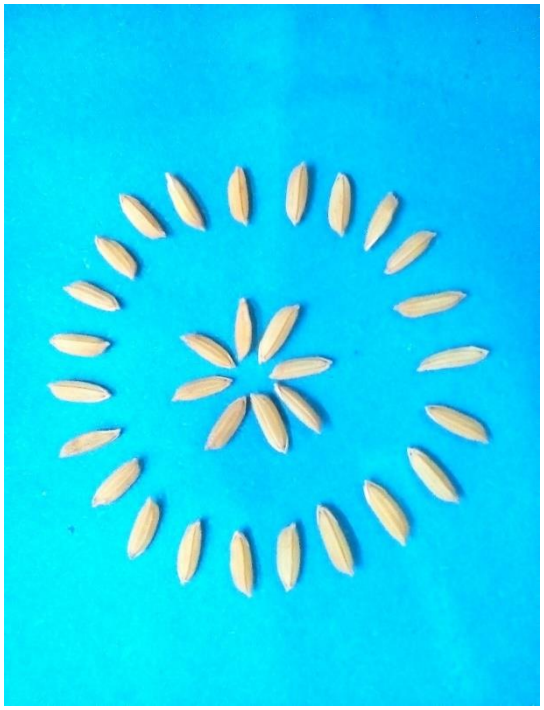

Plate 25. Long type grain length

Plate 26. Very long type grain length.

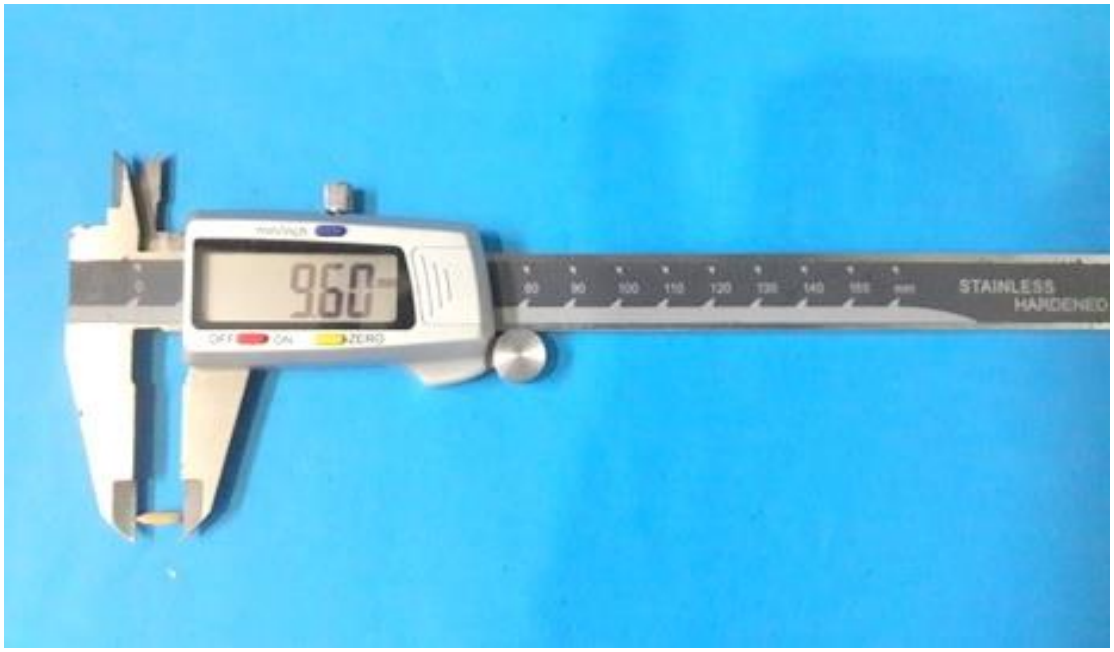

Plate 27. Measurement of grain length

4.2.9 Sterile Lemma Length: Measure at postharvest stage

Ten grains from every lines were measured and the mean value was recorded. Sterile lemma length of the lines ranged from 2.21 mm to 3.11 mm with a mean value of 2.62 mm (Appendix-V). On the basis of sterile lemma length, the observed lines were grouped as short (<1.5 mm), medium (1.5-2.5 mm), long (2.6-3.0 mm) and very Long (>3.0 mm). Four lines (L3, L4, L7 and L11) were recorded as medium sterile lemma length, seven lines (L2, L5, L6, L8, L9, L10 and L12) as long type sterile lemma length and rest one lines (L1) as very long type sterile lemma length (Table 38). No lines were found as short type.

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 lines were measured and the mean value was recorded. Decorticated grain length of lines ranged from 6.18 mm to 7.61 mm with a mean value of 6.72 mm (Appendix-V). On the basis of decorticated grain length, the observed lines were grouped as short (<5.5 mm), medium (5.6-6.5 mm), long (6.6-7.5 mm) and very long (>7.5 mm). Six lines (L3, L4, L6, L7, L11 and L12) were recorded as medium type decorticated grain length, five lines (L2, L5, L8, L9 and L10) as long type decorticated grain length and rest one lines (L1) as very long type decorticated grain length (Table 39). No lines were found as short type decorticated grain length.

Table 38. 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	L3, L4, L7 and L11
Long	2.6-3.0 mm	5	L2, L5, L6, L8, L9, L10 and L12
Very long	>3.0 mm	7	G1
Range	(L4) 2.21 mm - (L1) 3.11 mm		
Average	2.62 mm		

Table 39. 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, L4, L6, L7, L11 and L12
Long	6.6-7.5 mm	5	L2, L5, L8, L9 and L10
Very long	>7.5 mm	7	G1
Range	(L4) 6.18 mm - (L1) 7.61 mm		
Average	6.72 mm		

4.3 Variability among the twelve lines of 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 twelve lines of *Oryza sativa* L. are given in Table 40. Phenotypic variance, genotypic variance, phenotypic coefficient of variation and genotypic coefficient of variation for different yield related characters are presented in Table 42.

4.3.1 Days to maturity

Significant variations were observed among the lines (58.18*) for days to maturity (Table 40). The highest days to maturity was taken in L12 (146 days) and the minimum days to maturity was taken in L3 (133 days). Variations at 80% maturity stage in different lines are presented in Plate 28.The lines L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10 were shown lower days to maturity than the checks L11 (BRRI Dhan28) (145 days) and L12 (BRRI Dhan29) (146 days).The phenotypic and genotypic variance for days to maturity was observed (20.35) and (18.92) respectively suggested that the environment had significant role in the expression of trait. The phenotypic coefficient of variation (3.30%) was higher than genotypic coefficient of variation (3.12%) (Table 42) 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.

4.3.2 Plant height (cm)

The highest plant height was observed in L7 (102.71 cm) whereas the minimum plant height was observed in L2 (79.71 cm) which is near to L5 (80.11 cm) and L8 (80.45 cm) (Table 41) (Figure 10). The lines L2 (79.71 cm), L5 (80.11 cm), L8 (80.45 cm), L9 (81.43 cm) and L4 (85.40 cm) were shown lower plant height than two checks L11 (BRRI Dhan28) (89.88 cm) and L12 (BRRI Dhan29) (91.77 cm). Phenotypic variance and genotypic variance were observed as 55.92 and 51.99 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 (8.44%) and the genotypic coefficient of variation (8.14%) also indicated presence of variability among the lines for this trait (Table 42). 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 twelve lines (10.24*) for number of total tillers per plant (Table 40). Among the twelve lines L9 (15 tillers) showed the maximum number of total tillers per plant and the minimum number of total tillers per plant showed by L4 (9 tillers) (Table 41) (Figure 11). The lines L10 (12 tillers), L5 (13 tillers), L2 (14 tillers), L7 (14 tillers), L8 (15 tillers) and L9 (15 tillers) were produced higher number of tillers per plant than the checks L11 (BRRI Dhan28) (12 tillers) and L12 (BRRI Dhan29) (13 tillers). Number of total tillers per plant showed phenotypic variance (4.45) is higher than genotypic variance (2.89) indicating moderate environmental influence on these characters and high difference between the phenotypic coefficient of variation (16.46%) and the genotypic coefficient of variation (13.27%) value indicating that this trait is highly influenced by the environment (Table 42). Ghosal *et al*. (2010) reported similar result for this trait in irrigated rice.

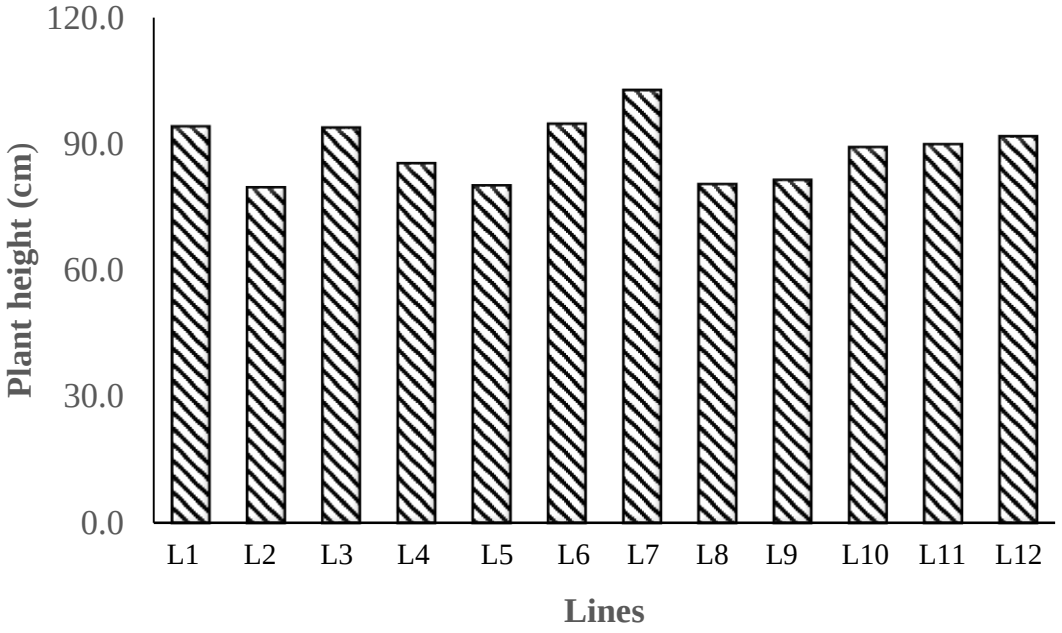

Figure 10. Variations in Plant height (cm).

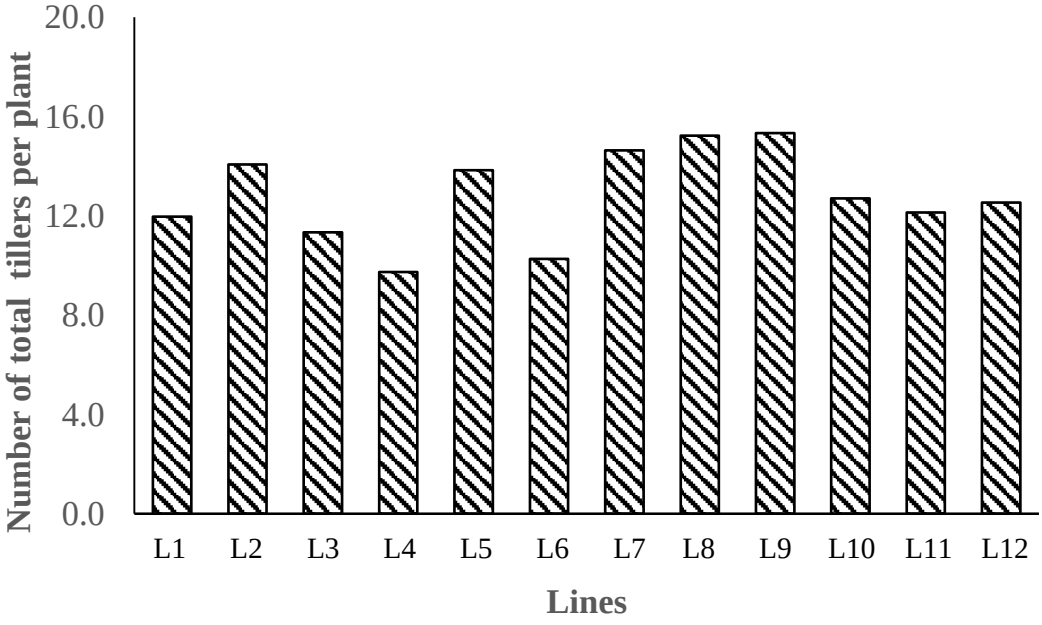

Figure 11. Variations in number of total tillers per plant.

Table 40. Analysis of variances for twelve important characters of twelve lines of (*Oryza sativa* L.)

Source of variation	df	Mean sum of squares (MSS)											
		characters											
		DM	PH (cm)	NTT	NET	LP	NPBP	NSBP	TSP	NFG/P	NUFG/P	TSW (gm)	Y/H (t/ha)
Replication	2	1.58	78.12	5.00	5.73	2.64	0.14	2.27	132.13	487.40	208.69	0.04	0.32
Lines	11	58.18*	159.90*	10.24*	10.35*	2.32*	1.50*	27.04*	328.36*	191.01*	347.21*	8.69*	1.10*
Error	22	1.43	3.92	1.55	1.67	0.69	0.21	5.84	111.49	89.98	28.20	0.46	0.31

* = significant at the 0.05 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 41. Mean performance of twelve lines of (*Oryza sativa* L.) in respect of six important characters

Lines	DM	PH (cm)	NTT	NET	LP (cm)	NPBP
L1	135	94.14	11	11	24.75	8.47
L2	135	79.71	14	13	22.12	8.40
L3	133	93.84	11	10	22.82	9.60
L4	134	85.40	9	9	22.64	9.67
L5	134	80.11	13	13	21.94	7.90
L6	136	94.75	10	9	23.37	9.50
L7	134	102.71	14	13	22.84	9.40
L8	134	80.45	15	14	22.00	7.80
L9	134	81.43	15	15	21.94	8.17
L10	135	89.16	12	12	21.79	9.40
L11	145	89.88	12	11	22.97	8.23
L12	146	91.77	13	12	23.68	8.43
Mean	136	88.61	12	12	22.74	8.75
Max	146	102.71	15	15	24.75	9.67
Min	133	79.71	9	9	21.79	7.80
CV%	0.88	2.24	9	10.43	3.66	5.24

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

Table 41. Mean performance of twelve lines of (*Oryza sativa* L.) in respect of six important characters (cont'd)

Lines	NSBP	NFG/P	NUFG/P	TSP	TSW (gm)	Y/H (t/ha)
L1	30.30	124.57	30.43	155.00	23.40	7.63
L2	24.80	129.47	11.53	141.53	26.90	8.97
L3	26.97	130.27	20.60	150.87	27.73	8.79
L4	29.33	142.30	22.83	165.17	25.37	9.43
L5	23.17	130.47	9.13	139.87	24.34	9.27
L6	23.93	125.97	17.90	143.87	25.23	8.12
L7	31.27	113.93	47.47	161.40	21.46	8.19
L8	24.13	129.94	12.43	142.37	24.03	9.19
L9	26.90	135.13	11.37	146.47	23.88	9.61
L10	32.17	144.07	29.20	173.83	23.18	8.33
L11	26.00	125.87	23.17	148.90	25.27	8.45
L12	26.80	132.17	19.30	151.47	25.73	8.37
Mean	27.15	130.34	21.28	151.73	24.71	8.69
Max	32.17	144.07	47.47	173.83	27.73	9.61
Min	23.17	113.93	9.13	139.87	21.46	7.63
CV%	27.15	7.28	24.95	6.96	2.75	6.44

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 42. Estimates of genetic parameters in twelve important characters of twelve advanced lines of boro rice (*Oryza sativa* L.)

Characters	σ2p	σ2g	PCV (%)	GCV (%)
DM	20.35	18.92	3.30	3.12
PH	55.92	51.99	8.44	8.14
NTT	4.45	2.89	16.46	13.27
NET	4.57	2.89	17.24	13.71
LP	1.23	0.57	4.88	3.23
NPBP	0.64	0.43	9.15	7.51
NSBP	12.91	7.07	13.24	9.79
NFG/P	123.65	33.68	8.53	4.45
NUFGP	134.54	106.34	54.50	48.45
TSP	183.78	72.29	8.93	5.60
TSW	3.21	2.74	7.25	6.70
Y/H	1.10	0.79	12.06	10.22

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

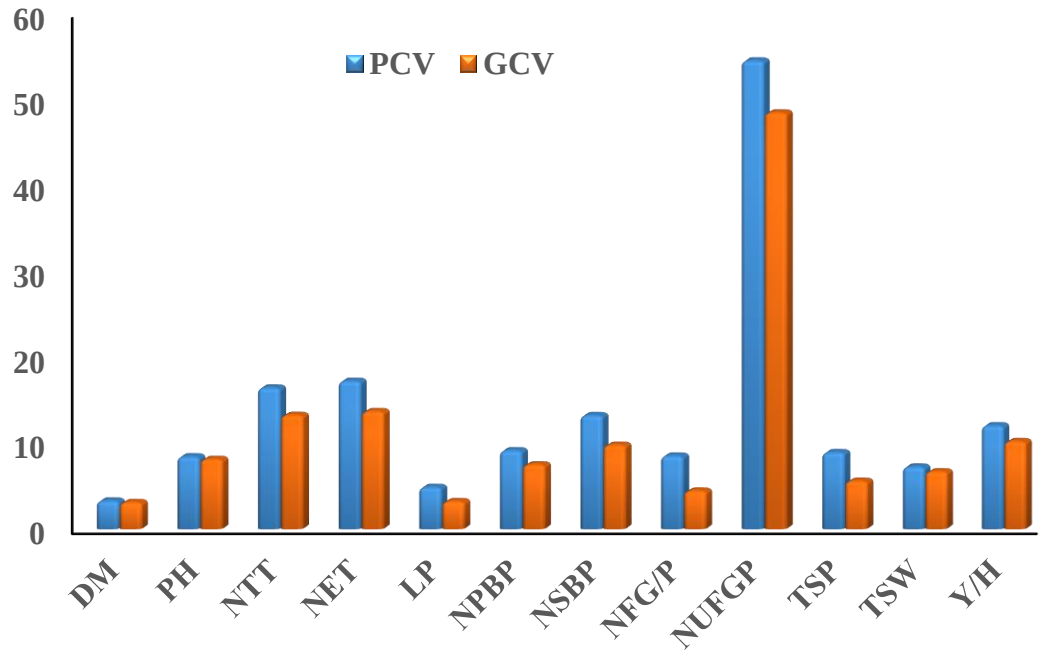

Figure 12: Genotypic and phenotypic co-efficient of variation of twelve advanced lines of Boro rice

4.3.4 Number of effective tillers per plant

Analysis of variance (Table 40) revealed significant differences among the lines (10.35*) for number of effective tillers per plant. The highest number of effective tillers per plant was recorded in L9 (15 tillers) whereas the minimum number of effective tillers per plant was recorded in L4 (9 tillers) (Table 41). The lines L10 (12 tillers), L5 (13 tillers), L2 (13 tillers), L7 (13 tillers), L8 (14 tillers) and L9 (15 tillers) produced higher number of effective tiller per plant than two checks L11 (BRRI Dhan28) (11 tillers) and L12 (BRRI Dhan29) (12 tillers). Phenotypic variance (4.57) was high different from the genotypic variance (2.89) that indicated high environmental effect over the trait. Large difference between the phenotypic coefficient of variation (17.24%) and the genotypic coefficient of variation (13.71%) values indicated that high influence of environment on this character (Table 42). Ghosal *et al*. (2010) reported similar result for this trait in rice.

4.3.5 Panicle length (cm)

From ANOVA table (Table 40) significant difference were observed among twelve lines (2.32*) for panicle length. Among the twelve lines the highest panicle length was observed in L1 (24.75 cm) and the lowest panicle length was observed in L10 (21.79 cm) (Table 41). The lines L2 (22.12 cm), L4 (22.64 cm), L3 (22.82 cm) and L7 (22.84 cm) produced almost similar panicle length with the check L11 (BRRI Dhan28) (22.97 cm) and the lines L6 (23.37 cm) produced almost similar panicle length with the check L12 (BRRI Dhan29) (23.68 cm). Variations of panicle length in different lines are presented in Plate 29. Panicle length showed less difference between phenotypic variance (1.23) and genotypic variance (0.57) indicating less environmental influence on these character and low difference between PCV (4.88%) and GCV (3.23%) value indicating the apparent variation due to lines with little low influence of environment (Table 42). Low phenotypic coefficient of variation than genotypic coefficient of variation for panicle length was reported by Kole *et al*. (2008) in rice.

Plate 28. Photograph showing variation at 80% maturity stage

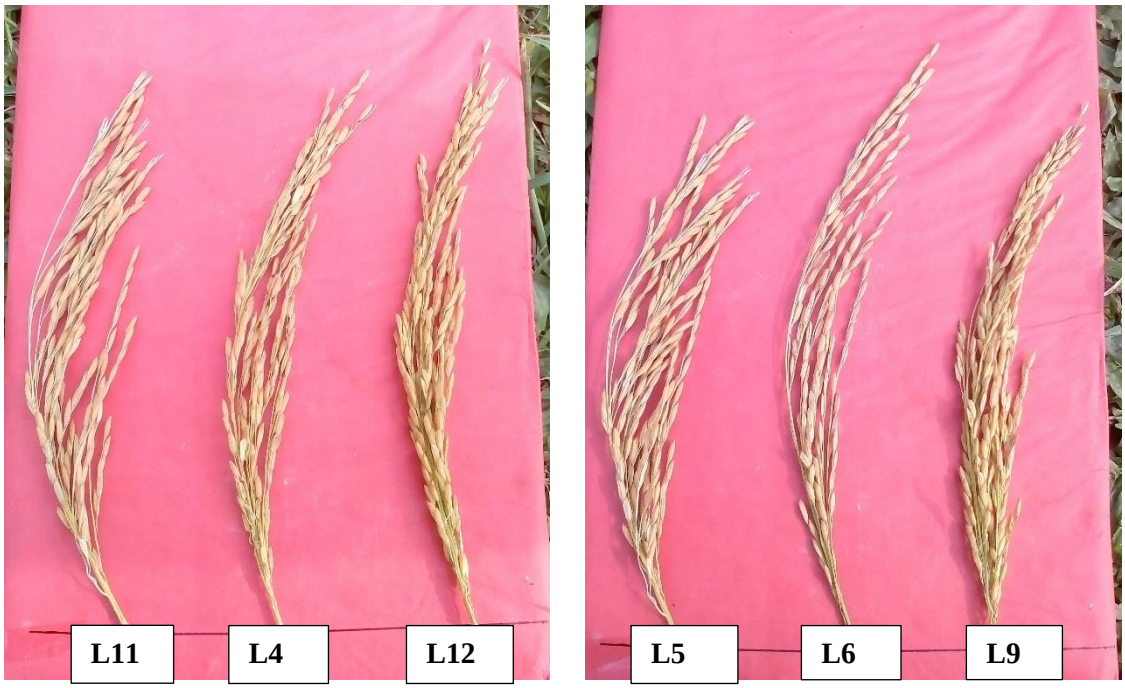

Plate 29. Photograph showing variation in panicle length in different lines

4.3.6 Number of primary branches per panicle

From ANOVA table (Table 40) significant difference were observed among twelve lines (1.50*) 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 L4 (9.67) which is very close to L6 (9.50) and L3 (9.60) while the minimum number of primary branches per panicle was recorded in L8 (7.80) (Table 41). The lines L7 (9.40), L10 (9.40), L6 (9.50), L3 (9.60) and L4 (9.67) were produced higher number of primary branches per panicle than the two checks L11 (BRRI Dhan28) (8.23) and L12 (BRRI Dhan29) (8.43). Number of primary branches per panicle showed the low phenotypic variance (0.64) and genotypic variance (0.43) which indicated less environmental influence. The phenotypic coefficient of variability (9.15%) values were recorded for number of primary branches per panicle very close to genotypic coefficient of variability (7.51%) 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 twelve lines (27.04*) for number of secondary branches per panicle (Table 40). Among twelve lines, the highest number of secondary branches per panicle was recorded in L10 (32.17) whereas the minimum number of secondary branches per panicle was observed in L5 (23.17) which are very close to L6 (23.93) (Table 41). The lines L4 (29.33), L1 (30.30), L7 (31.27) and L10 (32.17) were produced higher number of secondary branches per panicle than two checks L11 (BRRI Dhan28) (26.00) and L12 (BRRI Dhan29) (26.80). The value of phenotypic and genotypic variance (12.91) and (7.07) respectively for number of secondary branches per panicle with high difference between them indicates high effect of environment on this character (Table 42). According to Table 42, PCV (13.24%) and GCV (9.79%) for number of secondary branches per panicle which indicate that sufficient variation exist 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 twelve lines, the number of filled grains per panicle was recorded highest in L10 (144.07) and minimum was recorded in L7 (113.93) (Table 41) (Figure 13). The lines L9 (135.13), L4 (142.30) and L10 (144.07) were found higher number of filled grains per panicle than two checks L11 (BRRI Dhan28) (125.87) and L12 (BRRI Dhan29) (132.17). The magnitude of difference between phenotypic variances (123.65) and genotypic variances (33.68) were higher for number of filled grains per panicle suggested that large environmental influence on this character (Table 42). The high value of phenotypic (8.53%) and genotypic coefficient of variance (4.45%) 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).

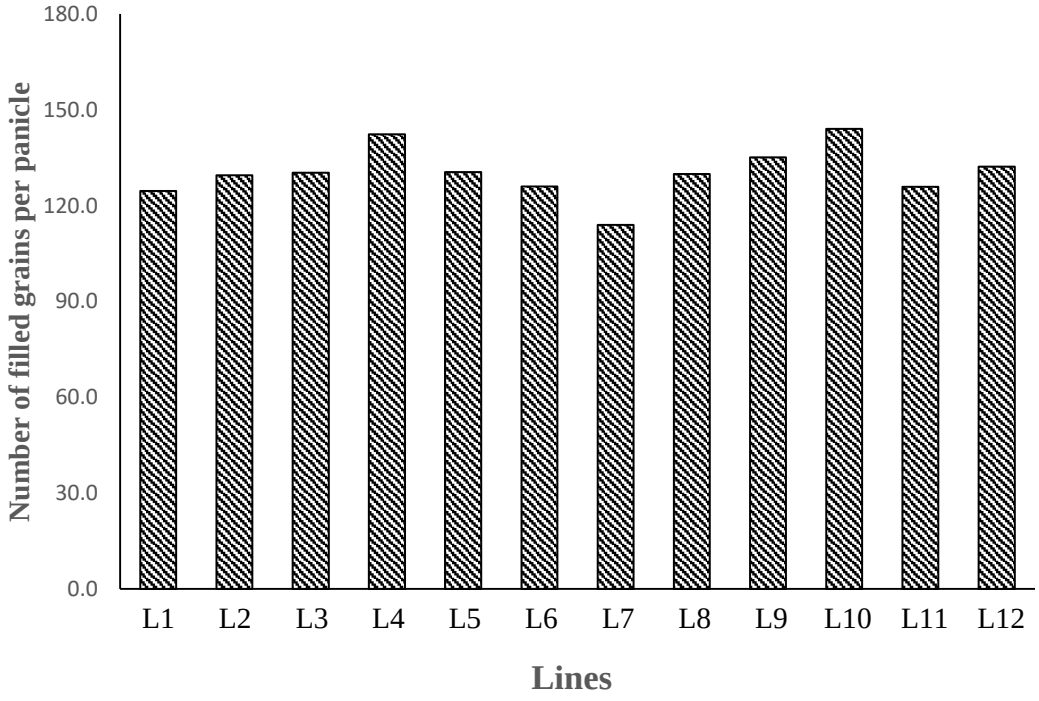

Figure 13. Variations in number of filled grains per panicle

4.3.9 Number of unfilled grains per panicle

Highly significant variation (347.21*) among twelve lines for number of unfilled grains per panicle (Table 40). The L7 showed the highest (47.47) number of unfilled grains per panicle among twelve genotypes whereas the L5 showed the minimum (9.13) number of unfilled grains per panicle (Table 41). The genotypes L6 (17.90), L8 (12.43), L2 (11.53), L9 (11.37) and L5 (9.13) was found to produce lower number of unfilled grains per panicle than two check varieties L11 (BRRI Dhan28) (23.17) and L12 (BRRI Dhan29) (19.30). The high value of phenotypic (134.54) and genotypic (106.34) 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 (54.50%) and genotypic (48.45%) coefficient of variances were high for number of unfilled grains per panicle which indicates the existence of adequate variation among the lines (Table 42).The highest phenotypic variance, genotypic variance and phenotypic coefficient of variance, genotypic coefficient of variance were also observed by Iftekharudduaula *et al*. (2001).

4.3.10 Total number of spikelet per panicle

From the ANOVA (Table 40), it was found that total number of spikelet per panicle showed significant variations among the lines (328.36*). The total number of spikelet per panicle was the maximum in L10 (173.83) and the minimum was observed in L5 (139.87) (Table 41) (Figure14) among twelve lines. The lines L1 (155.00), L7 (161.40), L4 (165.17) and L10 (173.83) were found higher number of spikelet per panicle than two checks L11 (148.90) and L12 (151.47). The phenotypic and genotypic variances for total number of spikelet per panicle were 183.78 and 72.29 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 8.93% and 5.60 % respectively for total number of spikelet per panicle which indicating that high variation exists among different lines (Table 42). 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 40), it was found that thousand seed weight showed significant variations among the lines (8.69*). Thousand seed weight was found the maximum in L3 (27.73 gm) whereas the minimum thousand seed weight was found in L7 (21.46 gm) (Table 41). Higher thousand seed weight was found in the lines L4 (25.37 gm), L2 (26.90 gm) and L3 (27.73 gm) than two check varieties the L11 (BRRI Dhan28) (25.27 gm) and L12 (BRRI Dhan29) (25.73 gm). The phenotypic variance (3.21) was higher than genotypic variance (2.74) indicating that environment has influence on expression of this character. The values of phenotypic coefficient of variation and genotypic coefficient of variation were 7.25% and 6.70% indicating that the line has considerable variation for this trait (Table 42). Bidhan *et al*. (2001) reported similar result for this trait.

4.3.12 Yield per hectare (t/ ha)

From the ANOVA (Table 40) revealed that the yield per hectare showed significant differences among the twelve lines (1.10*). Among the twelve lines L9 showed the maximum (9.61 t/ha) yield per hectare and the minimum by in L1 (7.63 t/ha) (Table 41), (Figure 15). The lines L3 (8.79 t/ha), L2 (8.97 t/ha), L8 (9.19 t/ha), L5 (9.27 t/ha), L4 (9.43 t/ha) and L9 (9.61 t/ha) were found higher yield per hectare than two check varieties L11 (BRRI Dhan28) (8.45 t/ha) and L12 (BRRI Dhan29) (8.33 t/ha). 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 (12.06%) and genotypic coefficient of variation (10.22%) indicates that this trait is influenced by the environment (Table 42). Pandey *et al.* (2010) reported low value of PCV and GCV for this trait.

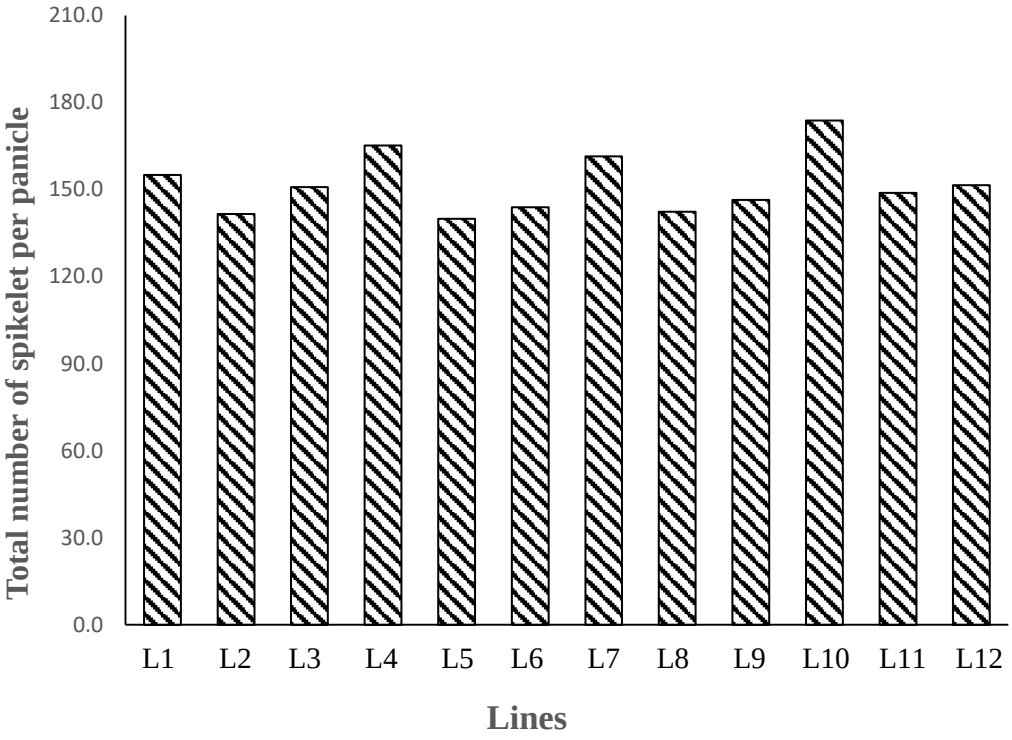

Figure 14. Variations in total number of spikelet per panicle

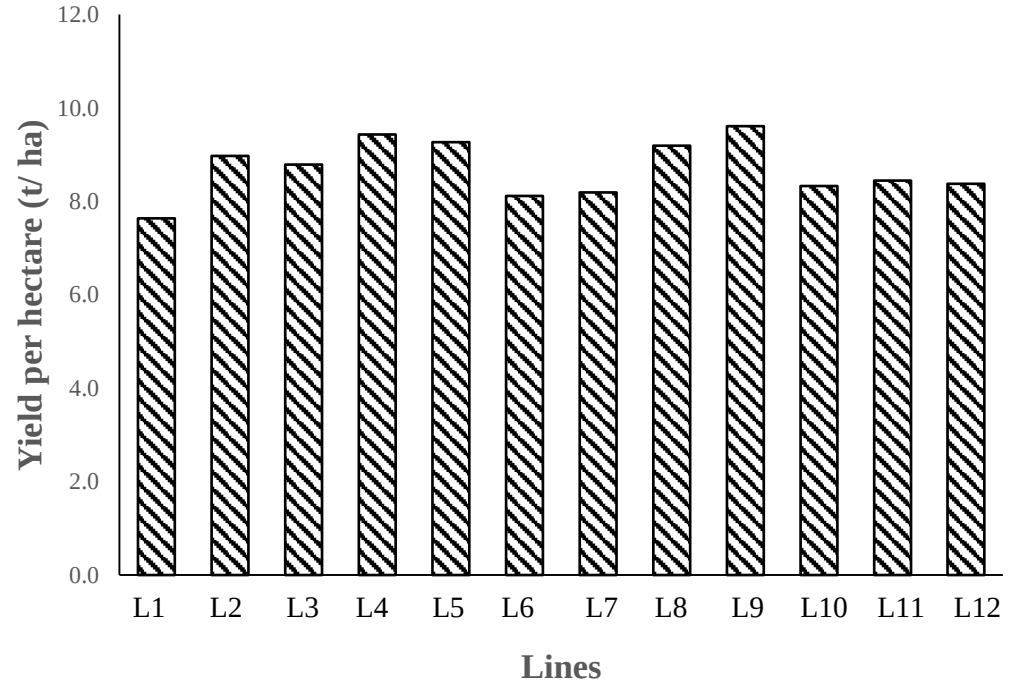

Figure 15. Variations in yield per hectare (t/ ha)

CHAPTER V

SUMMARY AND CONCLUSION

The present study was undertaken with ten advanced boro lines and two checks (BRRI dhan 28 and BRRI dhan 29) of *Oryza sativa* L. at the Sher-e-Bangla Agricultural University Farm, Dhaka, during November 2016 to April 2017. 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 variability of advanced lines on the basis of morphological, quality traits. Ten advanced lines and two checks were evaluated for thirty one 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 collor (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 I_2-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 were 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 seven lines (L1, L2, L5, L8, L9, L10 and L11) were absent or very weak type, four lines (L3, L4, L6 and L7) were medium hairs on the lower portion of the leaf type and one line L12 was very strong type. Three types of stigma exertion such as low type (L6, L8, L9, L11 and L12), medium type (L3, L5, L7 and L10) and high type (L1, L2 and L4) were observed. There are two types of flag leaf blade attitude such as erect type (L1, L2, L4, L5, L6, L7, L8, L9, L10, L11 and L12) and intermediate or semi-erect type (L3) were observed. In case of panicle curvature of main axis seven lines (L3, L4, L8, L9, L10, L11 and L12) were observed medium type and five lines (L1, L2, L5, L6 and L7) were observed strong type pattern between panicle and main axis. In panicle attitude of branches eleven lines (L2, L3, L4, L5, L6, L7, L8, L9, L10, L11 and L12) showed semi-erect type and rest one line (L1) showed spreading type. In case of panicle exertion two lines (L1 and L2) just exerted type, six lines (L3, L4, L5, L6, L9 and L12) moderately exerted type and four lines (L7, L8, L10 and L11) 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 L10 (21.79 cm) to L1 (24.75 cm) with a mean value of 22.74 cm where all lines showed medium type panicle length (21-25 cm).Culm length of observed lines ranged from L8 (54.94 cm) to L7 (75.67 cm) with a mean value of 63.95 cm. Among the twelve lines four short type lines (L2, L5, L8 and L9) and eight medium type lines (L1, L3, L4, L6, L7, L10, L11 and L12) were found. In case of number of effective tillers per plant lines (L1, L2, L3, L5, L7, L8, L9, L10, L11 and L12) showed variable types of effective tillers per plant (>10 tillers per plant). Thousand grain weight character results in better agronomic performance in which seven lines (L2, L4, L5, L6, L8, L11 and L12) showed high type of 1000 grain weight (24-27 gm/1000 grains) and (L3) showed very high type of 1000 grain weight (>27 gm/1000 grains). Decorticated grain length of observed lines ranged from L4 (6.18 mm) to L1 (7.61 mm) with a mean value of 6.72 mm. Single line L1 was very long type (>7.5 mm) and L2, L5, L8, L9 and L10 lines were long type (6.6-7.5 mm) of decorticated grain length.

For study of variability of boro lines, twelve yield attributing characters such as, days to maturity, plant height, number of total tillers per plant, number of effective tillers per plant, panicle length (cm), number of primary branches per panicle, number of secondary branches per panicle, number of filled grains per panicle, number of unfilled grains of per panicle, total number of spikelet per panicle, thousand seed weight and yield per hectare were recorded.

From variability analysis of twelve lines of *Oryza sativa* L., 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 L12 (146 days) and the minimum days to maturity was taken in L3 (133 days). Plant height exhibited highest in L7 (102.71cm) and lowest in L2 (79.71cm). Among the twelve lines L9 (15 tillers) showed the maximum number of total tillers per plant and the minimum one was in L4 (9 tillers).The highest number of effective tillers per plant was recorded in L9 (15 tillers) whereas the minimum number of effective tillers per plant was recorded in L4 (9 tillers). The highest panicle length was observed in L1 (24.75 cm) and the minimum panicle length was observed in L10 (21.79 cm). The Highest number of primary branches per panicle was recorded for L4 (9.67) while the minimum number of primary branches per panicle was recorded for L8 (7.80). The highest number of secondary branches per panicle was recorded in L10 (32.17) whereas the minimum number of secondary branches per panicle was observed in L5 (23.17). The number of filled grains per panicle was recorded highest in L10 (144.07) and minimum was recorded in L7 (113.93). The L7 (47.47) showed the highest number of unfilled grains per panicle and the L5 (9.13) showed the minimum number of unfilled grains per panicle. The total number of spikelet per panicle was maximum in L10 (173.83) and minimum was observed in L5 (139.87). Thousand seed weight was found maximum in L3 (27.73) whereas the minimum thousand seed weight was found in L7 (21.46). Among the twelve Lines L9 (9.61 t/ha) showed the maximum yield per hectare and the minimum one was in L7 (7.63 t/ ha).

The phenotypic variance of twelve lines was considerably higher than the genotypic variance for all the characters studied. Days to maturity, panicle length, number of primary branches per panicle, number of effective tillers per plant, thousand seed weight, and yield per hectare showed minimum difference between genotypic and phenotypic variance which indicated low environmental influence on these characters. Plant height, number of secondary branches per panicle, total number of spikelet per panicle, number of filled grains per panicle, number of unfilled grains per panicle, showed much difference between genotypic and phenotypic variance suggested that high environmental influence on expression of these characters.

Number of total tillers per plant, number of effective tillers per plant, number of secondary branches per panicle, total number of spikelet per panicle, number of filled grains per panicle, number of unfilled grains per panicle showed high difference between genotypic and phenotypic coefficient of variation indicated that high influence of environment on the expression of these characters. Plant height, Total number of spikelet per panicle, number of filled grain per panicle, number of unfilled grain per panicle, exhibited highest value of genotypic variance and genotypic phenotypic coefficient of variation. Days to maturity, panicle length, number of primary branches per panicle, thousand seed weight, and yield per hectare exhibited low difference genotypic and phenotypic coefficient of variation implies that low influence of environment and additive gene action on the expression of these characters.

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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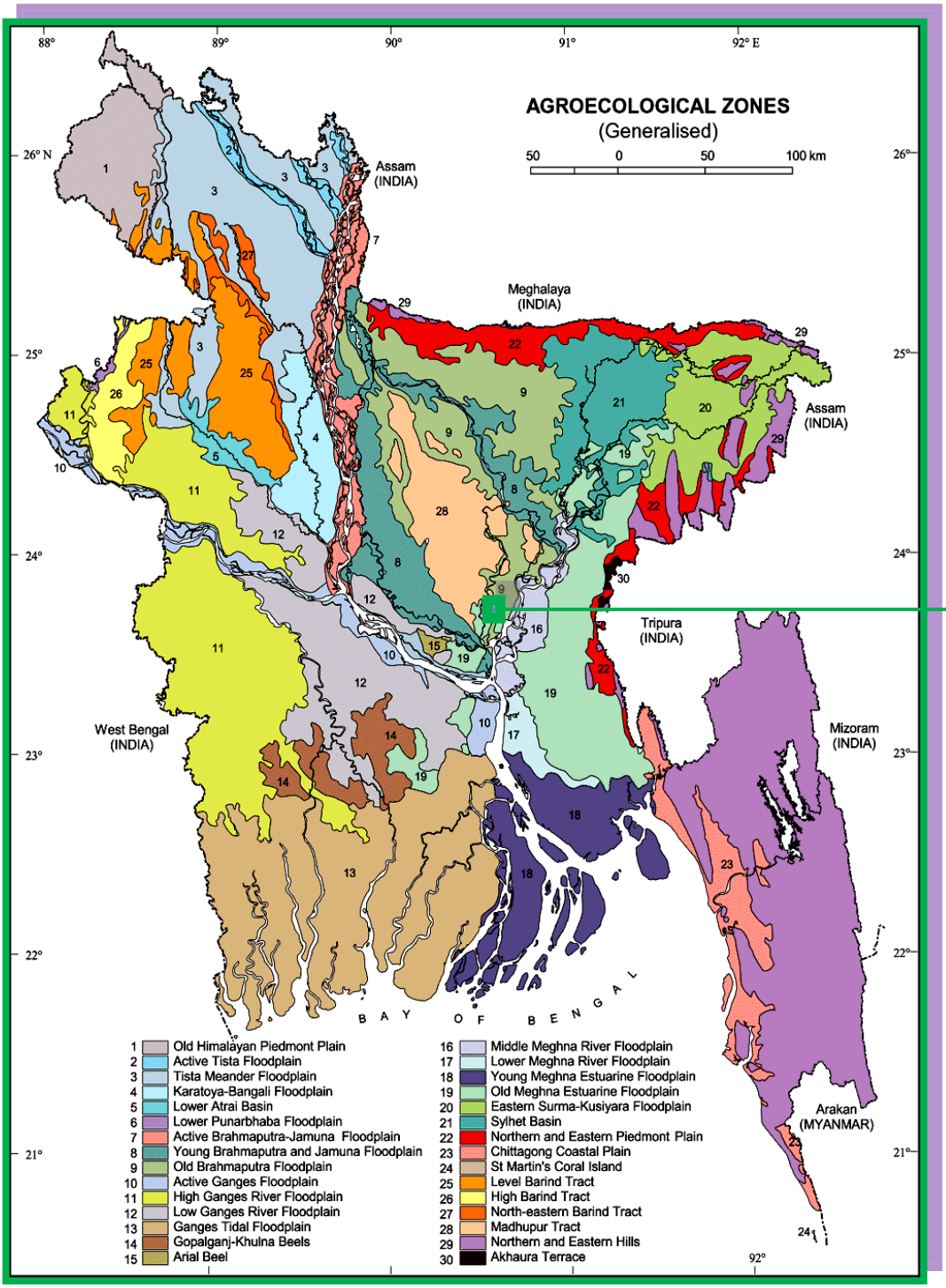
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. 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 auricles and collar	Absent-1, Present-9.
5	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 I_2-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.
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.

Appendix II. Cont'd

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 III. 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 IV. Mean performance of qualitative characters of twelve lines

Lines	LSAC	LC	PLP	PLACAC	PLL	PLSL	FLAB	MS	MOP	LPAC	LACBA	LACA	CS	SE
L1	1	2	1	1	9	3	1	1	7	1	1	1	1	7
L2	1	2	1	1	9	3	1	1	7	1	1	1	1	7
L3	1	2	5	1	9	3	3	1	7	1	1	1	1	5
L4	1	2	5	1	9	3	1	1	7	1	1	1	1	7
L5	1	2	1	1	9	3	1	1	7	1	1	1	1	5
L6	1	2	5	1	9	3	1	1	7	1	1	1	1	3
L7	1	2	5	1	9	3	1	1	7	1	1	1	1	5
L8	1	2	1	1	9	3	1	1	7	1	1	1	1	3
L9	1	2	1	1	9	3	1	1	7	1	1	1	1	3
L10	1	2	1	1	9	3	1	1	7	1	1	1	1	5
L11	1	2	1	1	9	3	1	1	7	1	1	1	1	3
L12	1	2	5	1	9	3	1	1	7	1	1	1	1	3

LSAC: Leaf Sheath Anthocyanin Color, **LC:** Leaf Color, **PLP:** Penultimate Leaf Pubescence, **PLACAC:** Penultimate Leaf Anthocyanin Coloration of Auricles and Collor, **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 I_2-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.

Appendix IV. Mean performance of qualitative characters of twelve lines (cont'd)

Lines	SACN	SACI	PCMA	SPLP	SCL	SAS	PAB	PE	LS	DGS	DGC	PGC	DGA
L1	1	1	7	5	2	1	5	5	1	9	1	3	1
L2	1	1	7	5	2	1	3	5	5	9	1	1	1
L3	1	1	5	5	2	1	3	7	5	9	1	1	1
L4	1	1	5	5	2	1	3	7	5	9	1	1	1
L5	1	1	7	5	2	1	3	7	1	9	1	1	1
L6	1	1	7	5	2	1	3	7	1	9	1	1	1
L7	1	1	7	5	2	1	3	9	5	9	1	3	1
L8	1	1	5	5	2	1	3	9	1	9	1	1	1
L9	1	1	5	5	2	1	3	7	1	9	1	1	1
L10	1	1	5	5	2	1	3	9	1	9	1	1	1
L11	1	1	5	5	2	1	3	9	5	9	1	1	1
L12	1	1	5	5	2	1	3	7	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.

Appendix V. Mean performance of quantitative characters of twelve lines

Lines	TH(Days)	CD(mm)	CL(cm)	PL(cm)	NET/P
L1	106	6.36	64.57	24.75	11
L2	106	5.10	56.85	22.12	13
L3	104	6.40	72.66	22.82	10
L4	102	5.85	62.38	22.64	9
L5	102	5.54	57.11	21.94	13
L6	108	6.13	68.33	23.36	9
L7	102	5.85	75.67	22.84	13
L8	103	6.30	54.94	21.99	14
L9	103	5.70	57.72	21.94	15
L10	107	6.50	65.83	21.79	12
L11	111	6.66	65.53	22.97	11
L12	115	6.90	65.74	23.68	12
Mean	106	6.11	63.95	22.74	12
Maximum	115	6.90	75.67	24.75	15
Minimum	102	5.10	54.94	21.79	9

TH=Time of Heading**, CD**=Stem**:** Culm Diameter, **CL**=Stem**:** Culm Length, **PL**= Panicle Length, **NET/P**=Number of Effective Tillers per Plant,

Appendix V. Mean performance of quantitative characters of twelve lines (Cont'd)

Lines	TM(Days)	TGW(gm)	GL(mm)	SLL(mm)	DGL(mm)
L1	135	23.4	10.36	3.11	7.61
L2	136	26.9	9.69	2.92	6.90
L3	133	27.73	8.91	2.41	6.41
L4	134	25.37	8.29	2.21	6.18
L5	134	24.34	9.30	2.64	6.92
L6	136	25.22	9.07	2.64	6.57
L7	134	21.46	8.58	2.21	6.56
L8	134	24.02	9.22	2.80	7.04
L9	134	23.88	9.15	2.66	6.88
L10	135	23.18	9.05	2.71	6.64
L11	145	25.26	9.10	2.55	6.55
L12	146	25.73	8.77	2.62	6.42
Mean	136	24.71	9.12	2.62	6.72
Maximum	146	27.73	10.36	3.11	7.61
Minimum	133	21.46	8.29	2.21	6.18

TM=Time of Maturity, **TGW**= Thousand Grain Weight, **GL**=Grain: length (without dehulling), **SLL**=Sterile lemma length: Measure at postharvest stage, **DGL**=Decorticated grain: length (After dehulling, before milling).

Appendix VI: Morphological, physical and chemical characteristics of initial soil (0-15 cm depth) of the experimental site

A. Physical composition of the soil

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

B. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N (kg/ha)	1790.00	Bremner and Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner, 1965
6	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7	Exchangeable K (kg/ha)	89.50	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	pH (1:2.5 soil to water)	5.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Source: Central library, Sher-e-Bangla Agricultural University, Dhaka.

Appendix VII. Monthly average Temperature, Relative Humidity and Total Rainfall of the experimental site during the period from December, 2016 to April, 2017

Month	Air temperature (°c)		Relative humidity (%)	Rainfall (mm) (total)
	Maximm	Minimum		
December, 2016	14	26	53	6
January, 2017	15	25	54	11
February, 2017	20	30	49	8
March, 2017	23	33	45	75
April, 2017	27	35	55	53

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