CHARACTERIZATION AND VARIABILITY ANALYSIS OF SEVERAL ADVANCED LINES OF BORO RICE (*Oryza sativa* L.)

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Dedicated to

MY BELOVED PARENTS,

TEACHERS AND FRIENDS

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This is to certify that thesis entitled, ***"CHARACTERIZATION AND VARIABILITY ANALYSIS OF SEVERAL ADVANCED LINES OF BORO RICE (Oryza sativa L.)"****submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in the Department of Genetics And Plant Breeding, embodies the result of a piece of bona fide research work carried out by* ***Md. Ashiqur Rahman****, Registration No.* ***18-09124*** *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.

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SOME COMMONLY USED ABBREVIATIONS

Full word	Abbreviation	Full word	Abbreviation
At the rate	@	Genetic Advance	GA
Agro-Ecological Zone	AEZ	Gross Domestic Product	GDP
Agriculture	*Agric.*	High Yielding Variety	HYV
Agricultural	*Agril.*	Indian Agricultural Research Institute	IARI
Agronomy	*Agron.*	International Rice Research Institute	IRRI
Bangladesh Agricultural Research Institute	BARI	Journal	J.
Bangladesh Bureau of Statistics	BBS	Kilogram	Kg
Bangladesh	BD	Meter	m
Bangladesh Economic Survey	BES	Millimeter	mm
Biological	*Biol.*	Murate of Potash	MP
Bangladesh Institute of Nuclear Agriculture	BINA	Negative logarithm of Hydrogen ion	pH
Bangladesh Rice	BR	Nitrogen	N
Breeding	*Breed.*	Percent	%
Bangladesh Rice Research Institute	BRRI	Phosphorous	P
Centimeter	cm	Potassium	K
Degree Celsius	^{o}C	Research	*Res.*
Department of Agricultural Extension	DAE	Randomized Complete Block Design	RCBD
Ecology	Ecol.	Sher-e-Bangla Agricultural University	SAU
Environment	*Env.*	Sulfur	S
And others	*et al.*	Square meter	m^2
Etcetera	etc.	Science	*Sci.*
Food and Agricultural Organization	FAO	West Africa Rice Development Association	WARDA
Gram	g		
Genotype	G		
Genetics	*Genet.*		

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ABSTRACT

The investigation was carried out under field conditions to characterize thirteen advanced lines of boro rice and to study their variability among these lines during the period of boro season (2018-2019) at the experimental field of Sher-e-Bangla Agricultural University, Dhaka. The Thirteen advanced lines were categorized for twenty qualitative and ten quantitative traits for following the release procedure. Variability study was carried out on twelve parameters to select the best lines for further trail. The lines were characterized and categorized as per the descriptors developed by Biodiversity International, IRRI and WARDA-2007 for DUS test of inbred rice. All the lines showed variation for twelve qualitative characters. They are green color intensity of leaf blade, flag leaf: attitude of the blade, lemma and palea: anthocyanin coloration, spikelet: color of the tip of lemma, panicle exertion, panicle: awns in the spikelet, attitude of branches culm habit, color of the stigma, ligule color, panicle exertion, leaf senescence, color of awns. Among the quantitative characteristics, culm length (cm), panicle length (cm), culm diameter, time of heading (50 % of the plants with head), effective tillers per hill, thousand seed weight (g), days to maturity, grain length (mm), grain width (mm) and yield per square meter(g) showed variation among the rice lines. In case of variability analysis ten parameters showed significant result viz. plant height (cm), no. of effective tillers per hill, panicle length (cm), number of secondary branches per panicle, number of filled grains per panicle, number of unfilled grains per panicle, thousand seed weight (g), days of 80 % maturity, yield per square meter (g) and yield per ha (t). Two parameters showed non-significant result *viz*. primary branch per panicle and grain length (mm). Minimum days to maturity were observed in G10 (130.56) followed by G11 (133.78), G07 (134.44), G05 (138.22) compared with the checks G14 (144.56) and G15 (140.56). Yield per ha (t) was highest in G01 (9.91 t/ha) followed by G13 (9.38 t/ha) compared with the checks G14 (9.5 t/ha) and G15 (9.22 t/ha). So, the most promising lines in respect of yield and time of maturity were G01, G10, G11 and G13 which could be used for further trail in future to follow the release procedure.

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family poaceae of tribe *Oryzeae*. The genus *Oryza* consists of two cultivated species *Oryza sativa* (Asian species) and (*Oryza glaberrima* (African species) and about 20 wild species (Vaughan *et al.,* 2003; Linscombe *et al.,* 2006). The cultivated species are *Oryza sativa* and *Oryza glaberrima*. *Oryza sativa* is grown all over the world while *Oryza glaberrima* has been cultivated in West Africa for the last ~3500 years (IRRI, 2007).

Rice (*Oryza sativa* L.) is one of the major staple food crops in the world and is particularly important in Asia where approximately 90% of world's rice is produced and consumed (khush, 2004; Zeigler and Barclay, 2008). Rice is the world's most important crop and the food security in Asia has been traditionally defined as having stable prices for rice in the major urban markets of a country. Rice is the staple food for more than 505 million of the population in Asia and for south asia alone, the figure is around 70% (Bishwajit *et al.,* 2013). Asia can be considered as 'Rice Basket' of the world, as more than 90% of the rice is produced and consumed in Asia. World paddy production area was 163.3 million hectares and production was 749.7 million tons (FAO, 2016).

Bangladesh is the fourth largest producer of rice in the world with the annual production of 34.90 million metric ton (USDA, 2019). Total area under Boro crop has been estimated at 118,32,309 acres (47,88,276 hectares) in this year (2018-19) as compared to 120,07,983 acres (48,59,367 hectares) of the last year (2017- 18). The harvested area has decreased by 1.46 % this year. Average yield rate of Boro in Financial Year 2018-19 has been estimated 4.0851 metric tons rice per hectare which was 4.028 metric tons per hectare in 2017-18. Total boro production of Financial Year 2018-19 has been estimated at 195,60,546 metric tons compared to 195,75,819 metric tons of Financial Year 2017-18 which is 0.078 % lower (BBS, 2019).

Agro-based developing country like Bangldesh is striving hard for rapid development for its economy. The economic development of the country is mainly based on agriculture and more particularly rice production. Rice (*Oryza sativa* L.)

contributes on an averages 20% on caloric intake of world population and 30% of population in Asian countries and this caloric contribution varies from 29.5% for China to 72% for Bangladesh (Calph and Prakash, 2007).

Improving the productivity of rice has become of immerse importance to feed nearly half of the world's population. Rice genetic resource is the primary material for rice improvement. Cultivated rice has undergone intensive selection during its domestication and genetic improvement. Moreover, modern rice improvement programs are continuously dependent on selection of desirable characteristics under highly controlled condition to achieve an ideotype, which exacerbates the reduction in the gene pool of cultivars (McCouch *et al.*, 2004). Agro-morphological characterization of germplasm accessions is fundamental in order to provide information for plant breeding programs (Lin *et al*., 1991).

Development of high yielding varieties through genetic improvement requires knowledge on the nature and magnitude of genetic variation governing the inheritance of quantitative characteristics, particularly yield and yield attributing characters. The understanding of genetic variability present in a given crop species for the traits under improvement is imperative for the success of any breeding program (Sankar *et al.*, 2006).

The information on genetic variation and heritability and genetic advance helps to predict the genetic gain that could be obtained in the later generations, if selection is made for improving the particular trait under study and findings were reported by Iftekharuddaula *et al.,* (2001); Gannamani (2001) and Sao (2002).

High phenotypic variations were composed of high genotypic variations and less of environmental variations, which indicates the presence of high genetic variability for different traits and less influence of environment. Therefore, selection on the basis of phenotype alone can be effective for these traits. Such results were observed by Shivani and Reddy (2000); Iftekharuddaula *et al.,* (2001) and Sao (2002).

Now, modern high yielding varieties in boro season are essential to increase the total rice production of Bangladesh. The high yielding advanced lines of boro rice were developed through crossing between Aus and boro rice with the intension to increase the yield of boro rice having genes from aus rice without much affecting the days of maturity. Thirteen boro rice lines were selected in the previous year which would be used in the study. To release a variety it is must to characterize the lines as per the descriptors developed by Biodiversity international, IRRI and WARDA-2007 for DUS test of inbred rice. So, the aim of the present study was to characterize the thirteen boro rice lines according to the descriptor and to study their variability for providing useful information which was the prerequisite to select the best boro rice lines for further trail to release as a variety.

OBJECTIVES

1. To characterize the advanced boro rice lines as per descriptors used for rice.

2. To find out the variability among the lines.

3. To select the best advanced line of boro rice on the basis of their shorter duration and higher yield.

CHAPTER II

REVIEW OF LITERATURE

Rice belongs to the species *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice). As a cereal grain, it is the most widely used staple food for a large part of the world's human population, especially in Asia. Yield of rice varieties is determined by various morphological parameters. The identification of suitable conditions of lines in comparison to the best parental varieties for yield and some important yield contributing characters with their variability are essential tool for a successful assessment. The present study aimed to access the performance of thirteen boro rice lines as compared to check varieties. For this assessment a field experiment was conducted at Sher-e-Bangla Agricultural University farm titled "Characterization and variability analysis of thirteen advanced lines of boro rice." Some related research findings of different researchers from home and abroad have been cited below:

2.1 Morphological characteristics

The assessment of genetic diversity is an integral part of any successful breeding program. Usually breeders have been employing morphological markers for genetic diversity estimation and a number of morphological descriptors in various crops are in vogue for characterization purpose (Rana and Bhat, 2004). Morphological characters of seeds such as seed coat color, seed shape, seed length, seed width, kernel length, kernel breadth, kernel shape, presence of awn, thousand seed weight etc. and traits of plants such as culm length, time of heading, time of maturity, number of primary branches, number of secondary branches, panicle length, numbers of effective tillers per plant, grains per panicle etc. can invariably be used in characterization of rice genotypes. Genetic studies have revealed that these characters are simply inherited and highly heritable and therefore, could be readily used in distinguishing varieties.

Das *et al*. (l992) evaluated 30 rice genotypes for variability analysis and found that plant height, days to 50% flowering, number of filled grains per panicle, panicle length, 1000-grains weight and days to maturity had high genetic coefficient of variation.

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.

Vivekzuradan and Subramanian (l993) evaluated 28 rice genotypes for the magnitude of genetic divergence using Mahalanobis's D_2 statistics. The population was grouped into five clusters. Plant height and grain yield contributed considerably, accounting for 85% of total divergence. The geographic diversity has not been found related to genetic diversity.

Choudhury *et al*. (1999) studied 64 indigenous rice varieties to know the nature and magnitude of genetic divergence among them. Based on nine agro-morphological characters, these genotypes were grouped into five clusters and found that plant height, tiller number, earliness, grain size and grain yield contributed considerably to total 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.

Pandey and Awasthy (2002) studied genetic variability of 21 genotypes of aromatic rice and reported significant genetic variability for plant height, days to 50% flowering, panicle per hill, panicle length, grains per panicle, grain length and breadth. They concluded that these traits play a major role in the enhancement of production of grain yield and serve as important criteria for screening germplasms to identify the suitable aromatic rice cultivars.

Roy *et al*. (2002) evaluated 50 rice cultivars for genetic diversity and responded that plant height, tiller numbers, panicle length, 100-grains weight, 100-kernel weight, filled grains/panicle and kernel-grain ratio contributed most towards divergence.

Mahto *et al*. (2003) evaluated twenty six early maturing upland rice genotypes for genetic variation, character association and path analysis based on days to 50% flowering, plant height, number of panicle per plant, panicle length, number of branches per particle, number of filled grains per panicle, 1000 seed weight and grain yield. The genotypic variance ranged from 5.36 for panicle length to 24.83 for grain yield. The difference between phenotypic and genotypic coefficient of variation was minimum for 1000 grain weight (0.12) and days to 50% flowering (0.13). High values of heritability were observed for 1000-grains weight (98.30%) and days to 50% flowering (97.33%). The number of grains per panicle and panicle length showed a significant difference between phenotypic and genotypic coefficient of variation. The association of high heritability with high genetic advance was observed for 1000-grain weight, days to 50% flowering, grain yield, number of branches per particle and plant height. Grain yield was positively and significantly correlated with days to 50% flowering, number of panicles per plant, number of branches per panicle and number of filled grains per panicle.

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.

Patil and Sarawgi (2003) studied genetic variation and correlation analyses in 128 aromatic rice accessions for 7 traits. The genetic and phenotypic coefficients of variation were high for number of unfilled grains per panicle, unfilled grain percentage, grain yield per plant, 1000 grains weight, number of ear-bearing tillers per plant, and number of filled grains per particle. High heritability estimates coupled with high genetic gain were recorded for grain yield per plant, number of ear-bearing tillers per plant, number of filled grains per panicle and unfilled grain percentage. The grain yield showed a positive and significant correlation with number of days to 50% flowering, plant height, number of ear bearing tillers per plant and number of filled grains per panicle at the genetic and phenotypic levels. Path analysis revealed that 1000 grains weight had the greatest positive direct effect on grain yield followed by number of ear-bearing tillers per plant, number of filled grains per particle and number of days to 50% flowering. However 1000-grains weight had no significant correlation with grain yield per plant due to its negative indirect effect on grain yield per plant through the number of filled grains per particle and plant height.

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 per plant.

Chaudhary *et al.* (2004) studied genetic variability, heritability and genetic advance for 17 quality and plant traits viz. kernel length, kernel length-breadth ratio, kernel length after cooking, length-breadth ratio of cooked rice, elongation ratio, elongation index, alkali spreading value, head rice recovery, milling percentage, panicle length, number of effective tillers per plant, number of fertile spikelet per panicle, spikelet density, spikelet sterility, biological yield, harvest index and grain yield per plant in 54 aromatic rice accessions. The phenotypic and genotypic coefficient of variation, heritability and genetic advance indicated that selection of genotypes may be carried out for kernel length-breadth ratio, length-breadth ratio of cooked rice and alkali spreading, value for quality traits in all the genotypes. All the traits exhibited high heritability coupled with high genetic advance and genetic variability.

Kisandu and Mghogho (2004) characterized two hundred and seventy five accessions from all rice growing regions of the Southern Highlands of Tanzania using morphological characters.

Other assessments included grain color, 1000 grains weight and milling characteristics were conducted. Using simple statistics, an analysis of variances for different characters was done and reported that a large number of names exist for rice cultivars. Different naming of varieties relates with differences in location and morphological appearance. In some cases, a single name can be given to different genotypes at different locations. High genetic diversity was observed for grain color, plant height (63 to l70 cm) and disease resistance. Grain color ranged from cream to blackish brown. On the other hand, cultivars did not show statistical differences on 100-grains weight. Indigenous cultivars showed small differences on heading and maturity rates. Some are highly aromatic and some had better milling quality.

A total of 124 landrace genotypes of rice were evaluated by Naheela *et al.* (2004) 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 best performance for individual character were identified.

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-grains weight, 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.

Zaman *et al*. (2004) evaluated 8 agro-morphological characters of 20 modern rice varieties for the magnitude of genetic divergence using Mahalanobis's D_2 statistics and reported that days to flowering and plant height contributed consistently to total divergence.

A study was conducted by Hossain *et al.* (2005) in order to investigating 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 BRRIdhan34 which identically followed by Kataribhog. The highest plant height was observed in Chinigura which was statistically similar to Kataribhog. The highest number of effective tillers/hill was observed in BRRIdhan37 and it was identically followed by Radhunipagal. Badshabhog, Chinigura, BRRIdhan38 and the lowest fertile tillers per hill was obtained from Kalijira. The highest number of grains per panicle was found in BRRIdhan34 and the lowest in BRRIdhan38. Maximum 1000 grains weight was observed in BRRIdhan38. In respect of yield BRRIdhan34 and Kataribhog are suitable for Dinajpur region in Bangladesh during T. aman season.

Fifty four elite rice genotypes were evaluated by Madhavilatha *et al.* (2005) 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.

Naik *et al.* (2006) estimated the nature and magnitude of diversity in fifty aromatic rice accessions including five scented improved varieties. Observations were recorded for 11 morphological and quality characters viz. plant height, panicle length, effective tillers per plant, biological yield per plant, seed length, seed breadth, seed length-breadth ratio, Kernel length, kernel breadth, kernel length-breadth ratio and grain yield per plant. The D_2 analysis indicated the presence of appreciable amount of genetic diversity in the material. The fifty genotypes were grouped into seven clusters. The cluster VI had the highest mean for grain yield per plant and for biological yield per plant. Inter cluster distance was recorded highest between cluster 3 and cluster 4. The least distance was recorded in cluster I and cluster 5. It was concluded that high variability was observed between the genotypes in different clusters for different characters.

Morphological characterization of ninety six landraces rice accessions were assessed by Ogunbayo *et al.* (2007) using 14 agro-botanical traits to study the variations and to select lines that could be used as potential parents. Highest yield was observed for accession 46 (DNN 184) with an average of 12 tillers, plant height of 136 cm and medium maturity date of 136 days. It was observed that number of total tillers per plant was not a functional of yield but rather these traits were significantly associated with plant height and maturity date. It was concluded that these landraces of rice accessions were associated with relatively narrow genetic base, positive heterosis could be promoted if any of the Gagnoa (GGA) accessions is used in a future hybridization program with Danane (DNN) accessions because of genetic distance between members of the two groups.

Bisne and Sarawgi (2008) characterized thirty two aromatic rice accessions of Badshahbhog group from IGKV germplasm, Raipur, Chhattisgar. These germplasm accessions were evaluated for 22 morphological, 6 agronomical and 8 quality characters viz. leaf blade pubescence, leaf blade color, basal leaf sheath color, flag leaf angle, Ligule color, collar color, auricle color, secondary branching of panicle, panicle thresh ability, awning, awn color, stigma color, lemma and palea color, lemma and palea pubescence etc. The specific genotypes B: 1340, B: 2039, B: 2495, B: 2816, B:16930, B: Z354, B1163, B: 2094 were identified for quality and agronomical characteristics. It was concluded that these accessions may be used in hybridization program to achieve desired segregants for good grain quality with higher yield.

Vcasey *et al*. (2008) characterized the genetic variability among species and populations of South American wild rice, eleven populations of *Oryza* *glumeapatula,* seven of *O. grandiglumis,* four of *O. latifolia*and one of *O. alta* from Brazil and Argentina. Univariate analysis were performed with 16 quantitative traits with the partitioning of populations within species. The high genetic variation among populations of *Oryza glumeapatula* was observed especially for the traits tiller number, plant height at flowering, days to heading, number of particles, panicle length, spikelet length and awn length. Significant differences ($p<0.001$) between species were observed for all the traits as well as among populations within the species. The most variable was *Oryza glumeapatula* followed by *O. latifolia*. Multivariate discriminant canonical and cluster analyses confirmed the separation of the highly diverse *Oryza glumeapatula* populations from the tetraploid species and the high genetic variation among *O. latifolia* populations.

A collection of 200 rice land races was assessed by Lang *et al.* (2009) for genetic diversity using quantitative agro-morphological characters. ANOVA showed highly significant differences (LSD 0.01) among the traits assessed such as grain length, grain width, number of unfilled grains, 1000 grains weight, leaf length and leaf width except panicles per plant and yield. Correlation coefficients showed that all the traits were highly correlated with each other except yield. The diversity indices (H') quantitative descriptors were high ranging from 0.68 to 0.95. Overall the mean diversity index for all traits was 0.88. Cluster analysis generated by UPGMA grouped the 200 rice landraces into six clusters with similarity coefficient of 20.61. The six clusters were distinct in terms of culm length, number of filled grains, panicle length, panicle per plant, grain length, grain width, yield and biomass.

Shahidulla *et al*. (2009) conducted an experiment to assess the genetic divergence of aromatic rice for grain quality and nutrition aspects. Forty genotypes composed of 32 local aromatic, five exotic aromatic and three non-aromatic rice varieties were used. Univariate and multivariate analyses were done. Enormous variations were observed in majority of characters viz. grain length, breadth, kernel weight, milling yield, kernel length, L/B ratio of kernel and volume expansion ratio (VER). In multivariate analysis, genotypes were grouped into six clusters. In the discriminant function analysis (DFA) function 1 alone absorbed 6l.7% of the total variance. The most contributing variables were kernel weight, kernel length and L/B ratio in function 1. The inter-cluster D2 value was maximum (26.53) between I and VI followed by 21.28 (between I and V). Minimum D_2 value was found (5.90) between II and III. Majority of the local aromatic rice varieties with smaller kernels were included in the cluster l. The cluster III contains Elai, Sarwati and Sugandha-I with long-slender kernel and “very good" appearance. Thus, they concluded that these varieties can be used in breeding program for improvement of germplasms in cluster-I.

An investigation was carried out by Shehata *et al.* (2009) to evaluate the morphological variation among Egyptian Jasmine and its 10M5 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.

Thayamanavan *et al*. (2001) evaluated genetic diversity among twenty six rice genotypes from four states of South Eastern Region of India using Mahalanobis‟s D_2 statistics. Based on 12 morphological and qualitative characters name, days to first flower, effective tillers per plant. panicle length, number of grains per panicle, 1000 grain weight, grain length, grain breadth, grain L/B ratio, kernel length, kernel breadth, kernel L/B ratio and grain yield per plant. These genotypes were grouped into 13 clusters. Genotypes from more than one place of origin were grouped in one cluster and genotypes from one state were grouped in more than one cluster. Geographical origin was not found to be a good parameter of genetic divergence. Cluster XII recorded highest mean value for grain yield per plant and lowest mean value for days to first flower. Number of grains per panicle followed by days to first flower contributed maximum to total divergence. Hybridization among genotypes AUR 4, Annamalan mutant poumani, Karnoolsona, Jecraga samba, AUR 7 and PY 5 from clusters III, II, XII and IX which had maximum inter-cluster distances and desirable values for days to first flower, number of grains per panicle, kernel length, kernel breadth, 1000- grain weight and grain yield per plant is likely to produce heterotic combinations and wide variability is segregating generations.

Miyagawa and Nakamura (1984) classified 85 aromatic rice cultivars based on the regional differences in varietal characteristics. Using principal component analysis, they divided the material into four major groups and found that the cultivars from Tohoku and Kanto area showed early maturity having shorter culms, longer awn, larger angle of flag leaf and yield. In Kinkind and Kyushu, the cultivars showed late maturity, and had longer culms, more straw height and yield. Cultivars from Shikoku differed from those of the warm areas of Kinkind and Kyushu. Similarly the cultivars from Hokuriku area were different from that of the other regions.

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

Twenty six aromatic rice germplasms collected from different parts of Orissa were evaluated for seed protein variability by Dikshit *et al.* (1992). Highly significant differences were reported for protein content, grain weight and L/B ratio. Some of the land races (Kalajira, Kanakpure) were found to have protein content in the range of 9-10 percent and more. The L/B ratio varied from l.6 to 3.5 with six collections characterized as long slender grain type: most notable among them were (Gidhanpakshi, Barhampuri, Badshahbhog and Durgahhog) kernel length of 7.7 to 6.6 mm.

Considerable genetic variability was recorded by Awasthi and Sharma (1996) for morphological traits in fifteen high quality aromatic rice genotypes grown at Faisabad. Maximum and minimum plant heights were recorded for Type-3 and Pusa-33 respectively, and maximum and minimum leaf lengths for Kasturi and Pusa-33 respectively. Highest number of nodes and internodes were recorded in Type-3 and Tilakchandan respectively. Color of leaves and magnitude of aroma also varied greatly with genotypes.

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. Morphologically, the local Japanese aromatic cultivars were divided into eastern and western groups. The former showed earlier heading, shorter culm, smaller panicle, lower yield, thinner stem and less tolerance to lodging than the latter. Foreign aromatic cultivars were similar to the Japanese ones in terms of long culm, heavy panicle and low yield, but they had poorer biomass and harvest index with later maturing and larger panicle. Local Japanese aromatic cultivars had longer and wider flag leaf, larger flag leaf angle, faster leaf senescence and longer neck inter node of panicle than the new cultivars.

Five aromatic and two non-aromatic milled rice samples were used by Sharp (2006) to compare the quality of U.S. produced aromatic rice with that of India and Thailand. Jasmine (Thailand) was whiter than all other rice samples tested. Della rice samples (U.S.) were not as white as Basmati (India). Della AR (Arkansas) was less red and less yellow than Della LA (Louisiana). While the uncooked kernels of Della were as long as Basmati or Jasmine, the greater length: width ratio caused Basmati to appear longer than Della. Della and Jasmine were greater than Basmati in 1000 kernel weight. Della samples were classified as having intermediate to high intermediate gelatinization temperature. Medium gel consistency, intermediate amylose content and cooking quality which are characteristics of typical U.S. long grain non-aromatic rice. A sensory panel could not detect a flavor difference between Della AR and either Basmati or Jasmine.

An investigation was conducted by Hien *et al.* (2007) to determine the extent of diversity and relationships among 36 aromatic rice cultivars collected from Asia. Characterization for 22 morphological characters with 101 morphological 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.

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.

2.2 Aroma of Rice

Rice is an important provider of nourishment for the world's population. Unlike most food crops, rice is generally eaten whole without seasoning, making the sensory properties of the rice grain itself important. Consequently, aroma and flavor have been rated as the major criteria for preference among consumers (Del Mundo and Juliano,

1981). There has been a quest for more than 30 years to understand the biochemical basis of rice flavor and aroma and how genetic, environment, cultural methods, drying, milling, storage, cooking method and other factors affect the aroma and flavor of cooked rice and to relate these effects to the numerous volatile compounds in rice (Champagne, 2008). However, this chapter discusses the causes of aroma and related reviews.

2.3 Causes of aroma

Buttery *et al.* (1983) isolated and identified 2-Acetyle-l-Pyrroline (ACPY) as an important compound contributing to the aromatic odor and they suggested that 2-acetylc-l-pyrroline was at major contributor to the popcorn-like aroma in several of the Asian aromatic rice varieties.

Hussain *et al.* (1987) compared the volatile profiles of an aromatic Basmati rice with anon-aromatic rice. More pentadecan-2-one, hexanol, and 2-pentylfuran were found in the Basmati rice.

Tanchotikul and Thomas (1991) extracted parts per billion (nanograms per grams) levels of a "popcorn" like aroma compound, 2-acetyle-l-pyrroline, from milled aromatic rice samples. Selected aromatic rice samples, including Della (USA), Basmati (Pakistan and India) and Jasmine (Thailand) were found to contain 2-acetyle-l-pyrroline in the range 76- 156 ppb. Plant breeders in the US developed a Jasmine type of aromatic rice (Jasmine 85) and the variety Della. When Thai taste panels evaluated Jasmine 85, it was criticized for its dull off-white color and less pronounced aroma (Rister *et al.*, 1992).

Mahatheeranont *et al.* (1995) identified different volatile compounds responsible for aroma of aromatic rice. They assumed that the compounds which played important role in aroma of rice were 2-acetyle-l-pyrroline as the major component.

2.4 Methods of aroma determination

Different techniques to detect aroma were developed by several scientists around the world. The method of heating of leaf tissues in water and noting the aroma was developed by Nagara *et al.* (1975). Chewing a few seeds was developed by Dhulappanavar (1976).

Sood and Siddiq (1978) developed a simple but rapid and reliable technique for quantifying aroma in aromatic rice. They used 2g leaf tissue, cut them into small pieces, kept them in small glass petri dish, added 10 ml 10% KOH solution and covered the petridish. After 10 minutes they smelt the petri dish and score aroma.

They also used stem, ovary, and kernel all plant parts except root to determine the aroma. Paule and Powers (1989) used two different panels to evaluate the character of four aromatic rice and two non-aromatic rice. The panel members evaluated the effluent peaks possessing the aromatic compound separated by gas chromatography. The peak containing 2-cetyle-l-pyrroline showed highly significant positive correlations with the sensory evaluation of the panel.

Nagaraju *et al.* (1991) in their study „A simple technique to detect scent in rice" developed a method for aroma detection in rice. For performing this test, 5.0 g dehusked kernel from each sample was taken in an air tight 20 ml vial the kernel were treated with 10 ml of 0.1 N KOH solution at 50° C for 4 to 5 minutes. After treatment the odor released from the vial was detected by olfaction. The work was done by selecting a panel of live judges scoring for the intensity of aroma. Their scores were averaged for the final rating.

IRRI (1996) developed a method for aroma test. According to this method, a rough grain was crushed and placed on a separate petridish of 5 cm diameter. Five ml of l.7% (0.3035N) solution of KOH was added to each petridish immediately after crushing and the petridish were covered. The aroma was determined by smelling one hour after crushing. After every 10 samples, one blank test was repeated to ensure the scent sensitivity.

Sarhadi *et al.* (2009) determined aromatic character by applying three methods, l.7% KOH sensory test, QC-MS-SIM and PCR analysis method during characterization of aroma in Afghan native rice cultivars along with Basmati 370 and Jasmine. Results of these three methods (Sensory test results. 2-AP concentration and Molecular marker) were found similar.

2.5 variability

Sao (2002); Iftekharudduala *et al.* (2011); Shivani and Reddy (2000) observed that high phenotypic variations were composed of high genotypic variations and less of environmental variations, which indicated the presence of high genetic variability for different traits and less influence of environment. Therefore, selection on the basis of phenotype alone can be effective for the improvement of these traits.

Sao (2002); Gannamani (2001) and Iftekharuddin *et al.* (2001) reported that the information on genetic variation, heritability and genetic advance helps to predict the genetic gain that could be obtained in later generations, if selection is made for improving the particular trait under study.

Padmaja Rao (1991) discovered 95% differences among five rice populations by using 20 morphological characters. The high-yielding genotypes were short. This feature was a result of short internode. This could equally be attributed to very effective assimilate partitioning at the expense of vegetative growth. So, instead of having tall plants, high yield came as a compensation for the vegetative deficiency. This trait is also advantageous in protection against lodging. Though plant height is mostly governed by the genetic makeup of the genotype, it is highly influenced by environmental factors. As indirectly point out earlier, rice yield is indirectly related to its height. This is due to sink competition for the limited photo synthates produced by limited sources. So what will be used for yield increase will be unnecessarily used for somatic cell enlargement that results in luxuriant vegetative growth and enhanced height. Therefore, tall varieties normally have lower yield than the short ones. Another serious disadvantage of tallness rice is lodging which significantly lowers the final yield and makes the plants prone to some other natural attacks. In this experiment, all the high-yielding varieties were observed to be of intermediate height. This implies that moderate plant height is desirable when breeding for high-yielding varieties.

Tripathi and Raj (2000) reported that flag leaf plays a significant role in enhancing rice yield because it remains the only source of assimilate production for the filing spikelets during grain-filling stage.

Ashrafuzzaman *et al.* (2009) observed that the larger the leaf area, the more the solar interception and photosynthate production provided that all other factors of production are not limiting. Therefore, flag leaf area was observed to be directly related to the yield components: no of panicles, panicle length, number of grains per panicle, 1000 seed weight, total grain weight per hill, and yield per hectare. Furthermore, the flag leaf has been observed to be metabolically active to support higher grain yield. Corroborating our findings in this work, it have made clear that yield components positively correlate with flag leaf area. Ashrafuzzaman *et al.* (2009) are reported that the weight of 100 or 1000 grain weight contributes significantly to the final yield per unit area. It represents the weight of individual seeds which could not be directly measured because of the size of individual seeds. The result of the present study showed that 100 grain weight varied significantly among the tested varieties. This could also be due to their differences in origin and genetic makeup.

Pandey and Anurag (2010) affirmed that number of tillers plays a significant role in determining yield of the rice grain since it is directly related to panicle number that will be produced per unit ground area. Fewer tiller results in fewer panicles, excess tillers cause high tiller abortion, small panicles, poor grain feeling and reduction in grain yield. He also observed that leaf area index and plant nitrogen status are the two major factors that affect tiller production in rice crops. When there is adequate nutrient supply, mitotic cell division will be enhanced and growth of tillers and plant general vegetative life will receive a boast. In this work, the tiller production was between moderate and low levels. So the cause of tiller abortion was not a problem during production period. The number of panicles per hill was between moderate and low. This correlates with the number of tillers produced.

Hasanuzzaman *et al.* (2008) reported that the number of effective tillers rests on the number of tillers produced and this is directly proportional to the panicles produced per unit area and finally depends on variety.

Mostajeran and Rahimi-Eichi (2009) observed that the fundamental factors responsible for variations in grain filling between the superior and inferior spikelets remain unknown. As it could be seen from this study, some varieties flower earlier than the others. Those that flowered earlier matured early while those that flowered late had a delay in their maturity. Early flowering indicates short life cycle and is considered a positive character for rice improvement.

Kush and Peng (1996) reported that early maturing varieties are advantageous in areas with short rainfall duration because they grow faster during the vegetative phase and are thus more competitive with weeds. They reduce weed control costs and utilize less water.

Bouman (2009) and Haefele (2009) affirmed that when drought occurs towards the reproductive stage of rice production, pollination, and fertilization as well as grain filling are severely affected and panicle blanking may result. In the situation, early maturing variety will give remedial measures in lieu of establishment of irrigation facilities and development of drought-tolerant varieties.

Biswas (1998) reported that varietal yield in this work was between high and low. Yield differences among different rice varieties have been reported anytime a comparison is made between different varieties of rice in both field and glasshouse trials.

Khanam *et al.* (2001) affirmed the differences are generally based, though environment has a great contribution in the manifestation of the inherent potential. In this work, the genotypes with higher number of effective tillers as well as higher number of grains per panicle also had higher yield.

Chakrabarti *et al.* (2010) observed that panicle length determines how many spikelets will be observed in a panicle and therefore filled spikelets and consequently final grain yield. The longer the panicle, the more the spikelets and the filled grains, if other environmental conditions are not limiting. As observed before, panicle length correlated positively with the final yield. Who also observed a significant positive association between panicle length and grain yield per hill.

Meenakshi *et al.* (1996) reported that heritability is the proportion of phenotypic traits (physical appearance) or total variance that is inherited from the parents. Higher genotypic coefficient of variation together with high heritability as well as high genetic advance gives better clues than individual parameters. Thus, the traits with high genotypic coefficient of variation, heritability, and genetic advance are selected. In this study, flag leaf length to width ratio, plant height, and the total number of grains per panicle had higher values for genetic coefficient of variation, heritability and genetic advance. Therefore, selection with a view to develop one trait which will positively influence other traits is of paramount importance. The contribution of individual panicle grain yield sums up to produce the final yield. Therefore, high panicle grain yield could be successfully used as an important selection index for grain yield.

Elsheikh *et al.* (2007) affirmed that when the panicle yield is correlated with the yield per unit area, positive correlation coefficient will result.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207, during December 2018 to June 2019. The location of the site was situated at 23°41'' N latitude and 90°22'' E longitude with an elevation of 8.6 meter from the sea level.

3.2 Climate and Soil

The experimental site was situated in the sub-tropical zone. The soil of the experimental site lies in Agro-ecological region of "Madhupur Tract" (AEZ No. 28). Its top soil is clay loam in texture and olive gray with common fine to medium distinct dark yellowish brown mottles. The pH is 4.47 to 5.63 and organic carbon content is 0.82%. The record of air temperature, humidity and rainfall during the period of experiment were noted from mini weather center of Sher-e-Bangla Agricultural University.

3.3 Planting materials

Fifteen rice genotypes were used in the study. The seeds of 13 genotypes were collected from germplasm centre of Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University and two germplasm were collected from BRRI. Descriptions of the genotypes are given in Table 1.

Table 1. List of materials used for the experiment

Genotypes	Accession no.	Source
G01	(14) special good yield	SAU
G02	(15) Richer	SAU
G03	(18) P-58	SAU
G04	(20) AL-104	SAU
G05	(21) AL-42	SAU
G06	(34) Hira	SAU
G07	(35) Aloron	SAU
G08	(43) Special from-129	SAU
G09	(48) Special from 17(iii)B	SAU
G10	(54) Special from AL-36	SAU
G11	(56) AL-18	SAU
G12	(57) AL-29	SAU
G13	(58) AL-36	SAU
G14	BRRI dhan 29	BRRI
G15	BRRI dhan 74	BRRI

G=Genotypes

3.4 Design and layout

The experiment was laid down in randomized complete block design (RCBD). The field was divided into three blocks; the blocks were sub-divided into 15 plots where genotypes were randomly assigned. The experimental field size was 26m x 16m where 1m boarder was maintained surrounding the field and every block. The experimental field was designed such a way where row to row distance was 30cm and plant to plant distance was 25cm. The 15 genotypes were distributed to each plot within each block randomly.

3.5 Raising of seedling

Seeds of all collected rice genotypes were sown on 15 December, 2018 in the seedbed separately and proper tags were maintained.

3.6 Preparation of main field

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

3.7 Application of fertilizers

Adequate soil fertility was maintained by applying of Urea, TSP, MP and Gypsum @260-77-79-55 kg/ha respectively. Total Urea was applied in three installments, at 20 DAT (days after transplanting), 40 DAT and 60 DAT recommended by BRRI.

3.8 Transplanting of seedling

Healthy seedlings of 30 days old were transplanted on 29 January 2019 in separate strip of experimental field. Water level was maintained properly after transplanting.

3.9 Intercultural operation and after care

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

3.9.1 Irrigation and drainage

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

3.9.2 Gap filling

First gap filling was done for all of the plots at eight days after transplanting (DAT). Second gap filling was done for some of the plots at 13 days after transplanting (DAT).

3.9.3 Weeding

The newly emerged weeds were uprooted carefully at tillering stage and panicle initiation stage by mechanical means.

3.9.4 Top dressing

After basal dose, the remaining doses of urea were top dressed in two equal installments**.**

3.9.5 Plant protection measure

Adequate control measures were taken against rice stem borer during tillering and heading stage of rice. Furadan 5G @ l kg per square meter was applied at active tillering stage and panicle initiation stage of rice for controlling rice yellow stem borer. Cupravit 80WP @ 2.5 g per liter water was applied against bacterial leaf blight of rice.

3.10 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 moisture content 12%.

3.11 Methods of recording of observations

To study the stable diagnostic characteristics data on the morphological characters were collected from five randomly selected hills from each replicated plots. The plants were selected from middle to avoid border effect. The mean was estimated from each plot. Twenty qualitative and ten quantitative traits were recorded using the descriptors developed by Bioversity International, IRRI and

WARDA, 2007. The descriptors are appended at the Table 2 and Table 3. In addition to the descriptors, the observed genotypes were classified according to Panse and Sukhatme (1995) and Naseem (2005). The observations for characterization were recorded under field condition as follows.

3.11.1 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 lines. Rice descriptors developed by the Biodiversity international, IRRI & WARDA-2007 (Appendix II) were used for data collection and recording. The photographs of specific trait considered to be helpful for identification of the lines were taken from the experimental field at appropriate times for different traits to compare the distinctness among the rice lines.

3.11.1.1 Basal leaf sheath color

Data of basal leaf sheath color was collected at late vegetative stage and the rice genotypes were classified into four groups with codes according to guided descriptors as

Green-1,
Green with purple lines-2,
Light purple-3,
Purple-4.

3.11.1.2 Green color intensity of leaf blade

Observations with respect to green coloration of leaf blade at late vegetative stage the rice genotypes were classified into four groups with codes according to guided descriptors as

No green (No green color visible due to anthocyanin)-0,
Light green-3,
Medium green-5,
Dark green-7.

3.11.1.3 Flag leaf attitude

Flag leaf attitude was determined by the angle of attachment between the flag leaf blade and the main panicle axis which was visually observed and classified into four groups as

Erect-1,
Semi-erect (intermediate)-3,
Horizontal-5,
Descending-7.
Which are shown in figure 1.

.

Erect Semi-erect Horizontal Descending

Figure 1. Flag leaf attitude

3.11.1.4 Leaf blade pubescence

It was assessed both visually and by touch. At late vegetative stage, rubbing fingers over the leaf surface from the tip to downwards and observed the genotypes. It is categorized into three groups as per descriptors as

Glabrous-1 (smooth-including ciliated margins),
Intermediate-2,
Pubescent-3.

3.11.1.5 Penultimate leaf: ligule

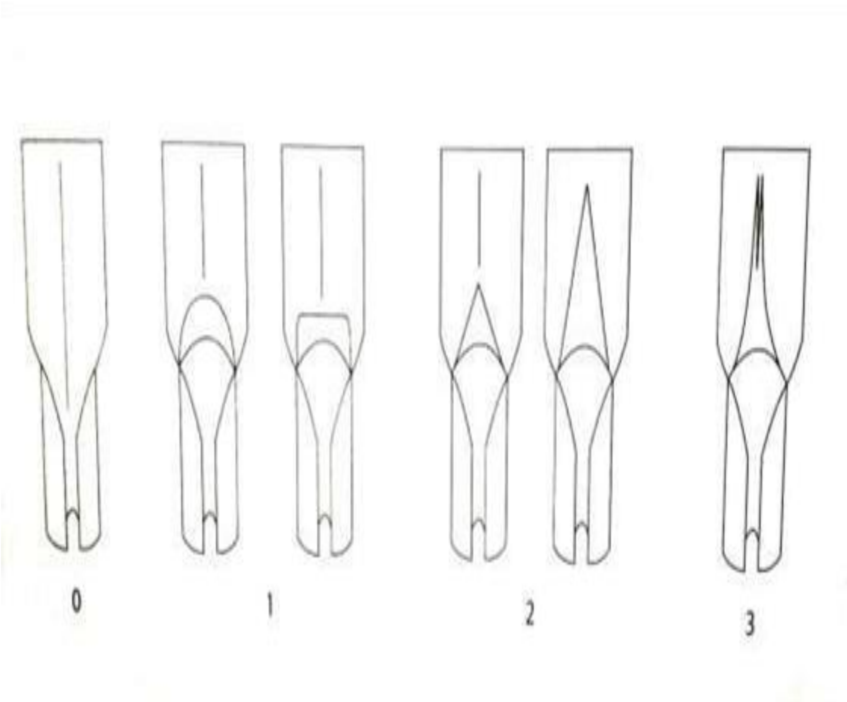
Based on presence of leaf ligule the rice genotypes were categorized as
Absent-1,
Present-9.

3.11.1.6 Penultimate leaf: Shape of the ligule

Shape of the penultimate leaf ligule was observed and the genotypes were categorized into four groups as

Absent-0,
Truncate-1,
Acute to acuminate-2,
Two - cleft-3.

which are shown hypothetically in Figure 2.



Absent Truncate Acute to acuminate Two cleft

Figure 2. Ligule shape

3.11.1.7 Ligule color

At late vegetative stage ligule color was visually observed and genotypes were categorized into six groups as

Absent (ligule less)-0,
Whitish-1,
Yellowish green-2,
Purple-3,
Light purple-4
Purple lines-5.

3.11.1.8 Color of stigma

Data was observed at anthesis period using a hand lens or magnifying glass and the rice 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,
Purple-5.

3.11.1.9 Auricle color

At late vegetative stage auricle color was visually observed and genotypes were categorized into four groups as

Absent (no auricles)-0,
Whitish-1,
Yellowish green-2,
Purple-3.

3.11.1.10 Lemma and palea: anthocyanin coloration

On the basis of lemma and palea anthocyanin coloration the observed genotypes were grouped as

Absent or very weak-1,
Weak-3,
Medium-5,
Strong-7,
Very strong-9.

3.11.1.11 Culm habit

Culm habit indicate the average angle of inclination of the base of the main culm from vertical (Figure 3). It was observed visually. Culm habit was categorized into five groups as

Erect (<15°)-1,
Semi-erect (intermediate) (~20°)-3,
Open (~40°)-5,
Spreading (>60 - 80°)-7,
Procumbent (culm or its lower part rests on ground surface)-9.

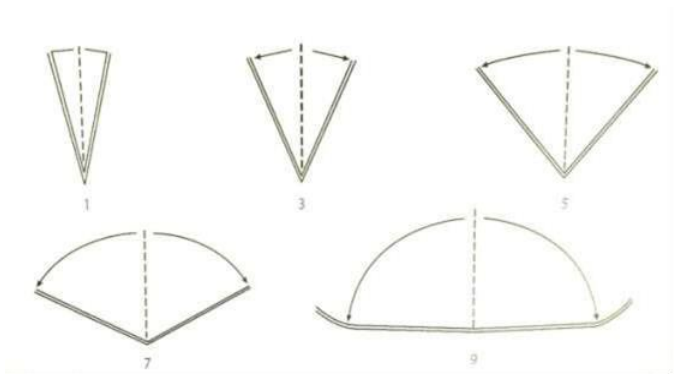
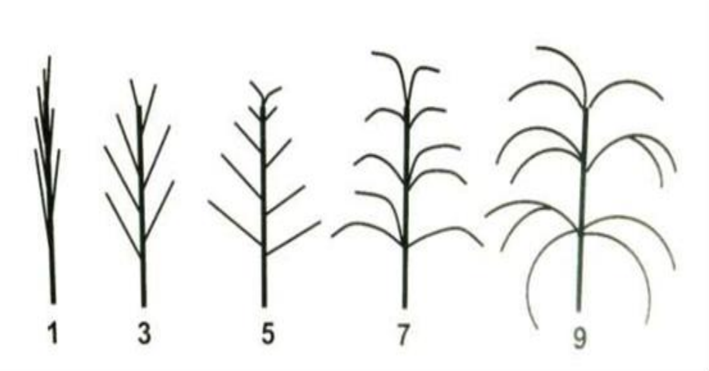


Figure 3. Culm habit

3.11.1.12 Panicle: attitude of branches

The attitude of branches were determined by the compactness of panicle. It was classified according to its mode of branching, angle of primary branches, and spikelet density. It was categorized into five groups as

Erect (compact panicle)-1,
Semi-erect (semi-compact panicle)-3,
Spreading (open panicle)-5,
Horizontal-7,
Drooping-9.
Which are shown in Figure 4.



Erect Semi -erect Spreading Horizontal Drooping

Fig 4. Attitude of branches

3.1.11.13 Panicle: exertion

Panicle exertion was observed at near maturity of genotypes. It was categorized into five groups as
Enclosed-1,
Partly exerted-3,
Just Exerted-5,
Moderately Exerted-7,
Well Exerted-9.

Which are shown in figure 5.

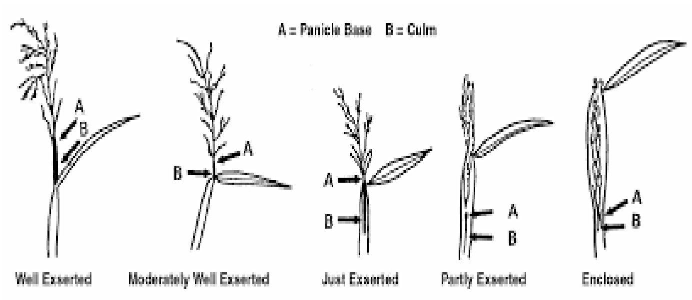


Fig 5. Exertion of panicle

3.11.1.14 Grain color (lemma and palea color)

Grain color was observed after harvest in presence of sufficient sun light and categorized into four groups as

Straw-1,
Golden-2,
Purple-4,
Black-5.

3.11.1.15 Color tip of lemma

Data was collected after anthesis and the genotypes were grouped as-

White-1,
Yellowish-2,
Brownish-3,
Red-4,
Purple-5,
Black-6.

3.11.1.16 Presence of awns

The observation was recorded after maturity and normally a character of wild species of rice and grouped as

Absent-0,
Partly awned-1,
Fully awned-2.

3.11.1.17 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 as follows

Tip only-3,
Upper half only-3,
Whole length-5.

3.11.1.18 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 as follows

Yellow white-1,
Brown-3,
Reddish-5,
Purple-7,
Black-9.

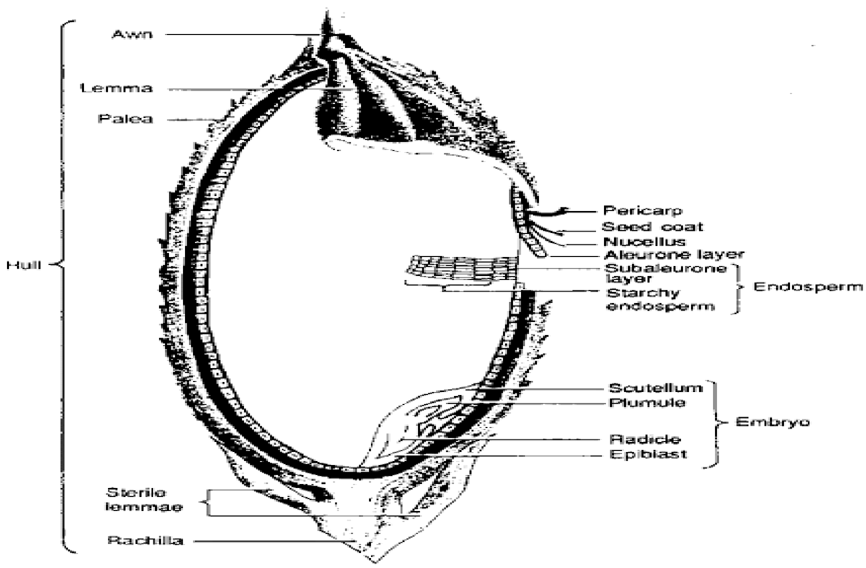


Fig.6 lemma and palea of rice

3.11.1.19 Leaf senescence

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

Late and slow (2 or more leaves retain green color at maturity)-1,
Intermediate-3,
Early and fast (leaves are dead at maturity)-9.

3.11.1.20 Caryopsis scent

Different techniques to detect aroma were developed by several scientists around the world. The method developed by IRRI (1996) for aroma test was followed. According to this method, a rough grain was crushed and placed on a separate petridish of 5 cm diameter. Five ml of 1.7% (0.3035N) solution of KOH was added to each petridish immediately after crushing and the petridish were covered. The aroma was determined by smelling one hour after crushing. The tested genotypes were grouped as

Non-scented-0,
Lightly scented-1,
Scented-2.

Table 2. Descriptors with codes for qualitative characteristics

Sl. no.	Characteristics	Descriptors with codes
1	Basal leaf sheath color	Green-1, Green with purple lines-2, Light purple-3, Purple-4.
2	Green color intensity of leaf blade	No green (No green color visible due to anthocyanin)-0, Light green-3, Medium green-5, Dark green-7.
3	Flag leaf attitude	Erect-1, Semi-erect (intermediate)-3, Horizontal-5, Descending-7
4	Leaf blade pubescence	Glabrous-1(smooth-including ciliated margins), Intermediate-2, Pubescent-3.
5	Penultimate leaf: ligule	Absent-1, present-9
6	Penultimate leaf: shape of the ligule	Absent-0, Truncate-1, Acute to acuminate-2, Two - cleft-3
7	Ligule color	Absent (ligule less)-0, Whitish-1, Yellowish green-2, Purple-3, Light purple-4, Purple lines-5.
8	Color of stigma	White-1, Light green-2, Yellow-3, Light purple-4, Purple-5
9	Auricle color	Absent (no auricles)-0, Whitish-1, Yellowish green-2, Purple-3
10	Lemma and palea: anthocyanin coloration	Absent or very weak-1, Weak-3, Medium-5, Strong-7 , Very strong-9

Table (Cont'd)

11	Culm habit	Erect (<15°)-1, Semi-erect (intermediate) (~20°)-3, Open (~40°)-5, Spreading (>60 - 80°)-7, Procumbent (culm or its lower part rests on ground surface)-9.
12	Panicle: Attitude of branches	Erect (compact panicle)-1, Semi-erect (semi-compact panicle)-3, spreading (open panicle)-5, Horizontal-7, Drooping-9.
13	Panicle: exertion	Enclosed-1, Partly exerted-3, Just Exerted-5, Moderately Exerted-7, Well Exerted-9.
14	Grain color:(Lemma and palea color)	Straw-1, Golden-2, Purple-4, Black-5.
15	Color tip of lemma	White-1, yellowish-2, brownish-3, red-4, purple-5, black-6.
16	Presence of awns	Absent-0, Partly awned-1, Fully awned-2.
17	Distribution of awns	Tip only-3, Upper half only-3, Whole length-5.
18	Color of awns	Yellow white-1, Brown-3, Reddish-5, Purple-7, Black-9.
19	Leaf senescence	Late and slow (2 or more leaves retain green color at maturity)-1, ntermediate-3, Early and fast (leaves are dead at maturity)-9.
20	Caryopsis scent	Non-scented-0, Lightly scented-1, Scented-2.

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

3.11.2 Quantitative traits evaluation methods

3.11.2.1 Culm length

Culm length was measured from ground level to the base of the panicle at maturity stage and categorized as

1- Very short (<50 cm),

2-Very short to short (51-70 cm),

3-Short (71-90 cm),

4- Short to intermediate (91-105 cm),

5- Intermediate (106-120 cm),

6- Intermediate to long (121-140 cm),

7- Long (141-155 cm),

8- Long to very long (156-180 cm)

9-Very long (>180 cm).

From figure 7. We can see the way to measure the culm length of a rice plant.

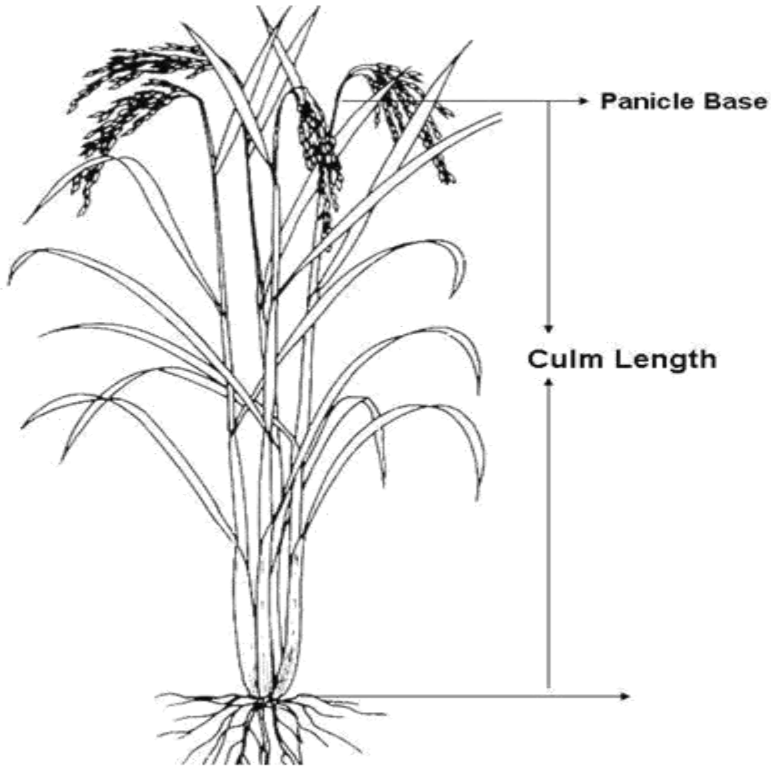


Figure 7. Culm length

3.11.2.2 Panicle length

Panicle length was counted randomly selected panicles of main tillers from five hills was measured from neck to the tip of the panicle of main tiller without awn in centimeters. According to the panicle length, the observed genotypes were classified into five different categories as

1- Very short (<11 cm),

3- Short (12-15 cm),

5-Medium (16-25 cm),

7- Long (26-35 cm),

9- Very long (>35cm).

3.11.2.3 Culm diameter

Culm diameter was measured from mother tillers at the lowest internode. Based on this character, the observed genotypes were classified as

1- Small (<5.0 mm),

3-Medium (5.1-6.0 mm),

5- Large (6.1-7.0 mm),

7- Very Large (>7.0 mm).

3.11.2.4 Time of heading (50% plants with heads)

The number of days from date of sowing to the 50% plants with heading in the plots was recorded on each individual plot and replication and the genotypes were classified as

1- Very early (<70 Days),

3-Early (70-85 Days),

5-Medium (86-105 Days),

7-Late (106-120 Days),

9-Very late (>120 days).

3.11.2.5 Effective tillers per hill

Effective tillers are the tiller which bears panicle. The number of effective tillers was counted from each of the sample plants and the average was taken. Based on this character, all the genotypes were grouped into three groups as

3-Low (<7 culms),

5-Intermediate (8- 12culms),

7- High (>15 culms).

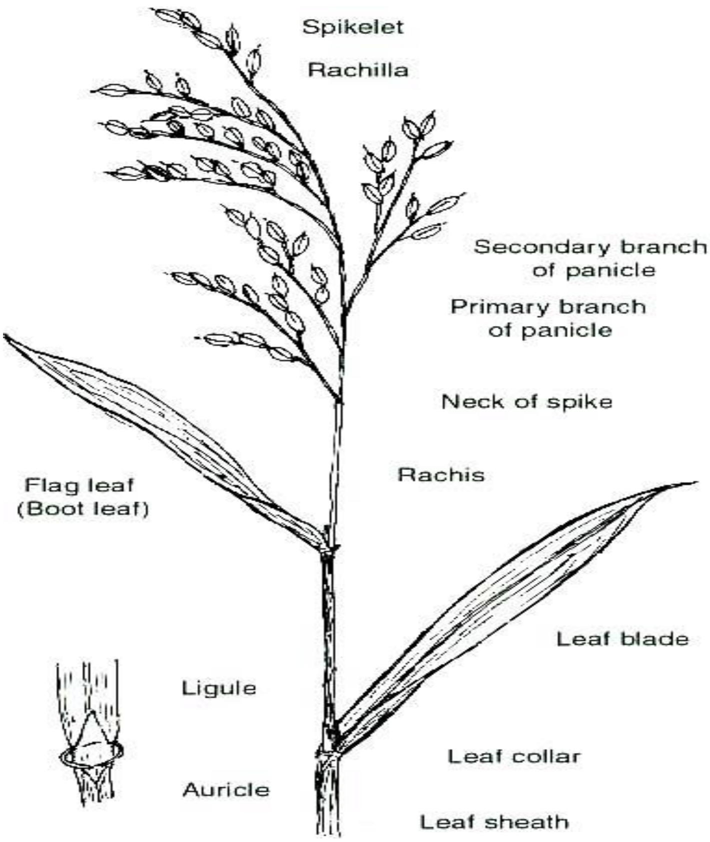


Figure 8. Morphology of a rice plant

3.11.2.6 Thousand seed weight (dry)

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 genotypes were categorized into five different groups as

1-Very low (<15g),

3-Low (16-19g),

5-Medium (20-23g),

7-High (24-27g).

3.11.2.7 Days to maturity

The number of days from date of sowing to the 80% seed maturity considering each replication was recorded on each individual plot and the genotypes were classified as

1-very early (<95 Days),

3-early (101-115 Days),

5-Medium (116-135 Days),

7-Late (136-150 Days),

9-Very Late (>150 Days).

3.11.2.8 Grain length (mm)

Grain length was measured in mm and a stereo-microscope was used for clear visualization. Five grains from every genotype were measured and the mean value was recorded. The genotypes were classified as

1-Short (<5.50 mm),

3-Medium (5.51-6.5 mm),

5-Long (6.51-7.5 mm),

7-Extra Long (>7.51 mm).

3.11.2.9 Grain width (mm)

Grain width was measured in mm and a stereo-microscope was used for clear visualization. Five grains from every genotypes were measured and the mean value was recorded. The genotypes were classified as

1-Fine (<2.5 mm),

3- Medium (2.51-3 mm),

5-Coarse (>3 mm).

3.11.2.10 Yield per square meter

All the plants of one square meter area per replication were threshed, seeds were sun dried for two days and weighed and then averaged. Seed yield was adjusted at 12% moisture content and the genotypes were categorized into three different groups as

1-Low (<450g),

3-Medium (450g - 650g),

5-High (>650g).

Table.3 Descriptions with codes for quantitative characters

Sl no.	characteristics	Descriptions with codes
1	Culm length	1-Very short (<50 cm), 2-Very short to short (51-70 cm), 3-Short (71-90 cm), 4-Short to intermediate (91-105 cm), 5-Intermediate (106-120 cm), 6-Intermediate to long (121-140 cm), 7-Long (141-155 cm), 8-Long to very long (156-180 cm), 9-Very long (>180 cm).
2	Panicle length	1-Very short (<11 cm), 3-Short (~15 cm), 5-Medium (~25 cm), 7-Long (~35 cm), 9-Very long (>40 cm).
3	Culm diameter	1- Small (<5.0 mm), 3-Medium (5.1-6.0 mm), 5- Large (6.1-7.0 mm), 7- Very Large (>7.0 mm).
4	Time of heading (50% plants with heads)	1- Very early (<70 Days), 3-Early (70-85 Days), 5-Medium (86-105 Days), 7-Late (106-120 Days), 9-Very late (>120 days).
5	Effective tillers per hill	3-Low (<7 culms), 5-Intermediate (8- 12culms), 7- High (>15 culms).
6	Thousand seed weight(dry)	1-Very low (<15g), 3-Low (16-19g), 5-Medium (20-23g), 7-High (24-27g).
7	Days to maturity	1-very early (<95 Days), 3-early (101-115 Days) 5-Medium (116-135 Days), 7-Late (136-150 Days), 9-Very Late (>150 Days).
8	Grain length	1-Short (<5.50 mm), 3-Medium (5.51-6.5 mm), 5-Long (6.51-7.5 mm), 7-Extra Long (>7.51 mm).

Table (Cont'd)

9	Grain width	1-Fine (<2.5 mm), 3- Medium (2.51-3 mm), 5-Coarse (>3 mm).
10	Yield per square meter	1-Low (<450g), 3-Medium (450g - 650g), 5-High (>650g).

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

3.12 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 and were not needed to statistical analysis.

3.13 Data collection for estimation of variability

Twelve quantitative parameters were used to study the variability. Five plants were selected randomly from every replication for each of the genotypes. Then the data were collected and averaged based on these following parameters:

3.13.1 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.

3.13.2 Number of effective tillers per hill

The number of effective tillers per hill was recorded as the number of panicle bearing tillers per hill and average value was recorded from five plants.

3.13.3 Panicle length (cm)

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

3.13.4 Number of primary branches per panicle

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

3.13.5 Number of secondary branches per panicle

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

3.13.6 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.

3.13.7 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.

3.13.8 Thousand seed weight (g)

One thousand seeds were counted randomly from cleaned seeds and then weighted in grains and recorded.

3.13.9 Grain length (mm)

Grain length was measured from five plants of each plot by slide calipers and recorded.

3.13.10 Days to maturity

Data was collected from planting to 80% maturity of the plant.

3.13.11 Yield per square meter

Plants from square meter area were collected then their grains harvested and sun dried. The dried yield was weighted separately and averaged.

3.13.12 Yield per hectare (t)

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

3.14 Estimation of variability

Collection data of the study were used to statistical analysis for each character. Analysis of variance (ANOVA), mean and range were calculated by using MS Excel and Statistix 10 software and then phenotypic, genotypic variance, environmental variance, PCV, GCV and ECV were estimated.

3.14.1 Analysis of variance (ANOVA)

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

Source of variation	D.F.	M.S	EMS	F-Ratio
Replication (r)	r-1	M1		M1/M2
Lines (l)	l-1	M2	$\sigma^2e + \sigma^2g$	M2/M3
Error	(r-1) (l-1)	M3	σ^2e	

Where,

r = Number of replications

l = Number of lines

D.F. = Degree of freedom

M.S. = Mean sum of square

EMS = Expected values of M.S.

3.14.2 Estimation of genetic parameters

The genetic parameters for the characters under study were estimated by the followings:

3.14.2.1 Estimation of variance components

Genotypic and phenotypic variances were estimated according to the formula below:

a. **Genotypic variance, $\sigma^2g = \frac{MSL-MSE}{r}$**

Where,

MSL = Mean sum of square for lines

MSE = Mean sum of square for error and

r = Number of replication

b. **Phenotypic variance, $\sigma^2p = \sigma^2g + \sigma^2e$**

Where,

σ^2g = Genotypic variance

σ^2e = Environmental variance = Mean square of error

3.14.2.2 Estimation of co-efficient of variation

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated by using the following formula:

Genotypic co-efficient of variance (GCV) (%) = $\frac{\sqrt{\sigma 2p}}{\bar{x}}$ x 100

Where,

σ^2g = Genotypic variance

$\bar{x}$ = Population mean

Phenotypic co-efficient of variance (PCV) (%) = = $\frac{\sqrt{\sigma 2g}}{\bar{x}}$ x 100

Where,

σ^2p = 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 thirty rice landraces as per the guided descriptors developed by BIOVERSITY INTERNATIONAL, IRRI and WARDA. 2007. Twenty quantitative and twenty qualitative characters were observed. Results have been compiled in tabular form according to descriptors and described by the following ways:

- Qualitative Characteristics
- Quantitative Characteristics

4.1 Qualitative Characteristics

4.1.1 Basal leaf sheath color

On the basis of basal leaf sheath coloration the observed genotypes were categorized as green-1, green with purple lines-2, light purple-3, purple-4. But there was no variation among the genotypes observed and all genotypes were found green color of basal leaf sheath (Table 4).

4.1.2 Green color intensity of leaf blade

Based on green color intensity of leaf blade the observed genotypes were categorized in 4 groups like no green- 0, light green-3, medium green-5 and dark green-7. Here 7 genotypes (G05, G06, G07, G09, G10, G12, G13) showed medium green color and rest 8 genotypes (G01, G02, G03, G04, G08, G11, G14, and G15) showed dark green color on leaf blade. No green type leaf blade was found in any genotypes (Table 5).

4.1.3 Flag leaf attitude

Based on angle of attachment between the flag leaf blade and the main panicle axis the observed genotypes were categorized in 4 groups like erect-1, semi-erect (intermediate)-3, horizontal-5 and descending-7 type. Here nine genotypes (G01, G02, G05, G08, G09, G10, G11, G12, G13) showed erect type flag leaf and 6 genotypes (G03, G04, GO6, G07, G14, G15) showed semi-erect type (Table 6).

Table 4. Categorization and grouping based on basal leaf sheath color

Types	Code	Genotypes
Green	1	G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15
Green with Purple lines		Nil
Light Purple	3	Nil
Purple	4	Nil

Table 5. Categorization and grouping based on Green color intensity of leaf blade

Types	Code	Genotypes
No Green	0	Nil
Light Green	3	Nil
Medium Green	5	G10 G12 G13 G14
Dark Green	7	G01 G02 G03 G04 G05 G06 G07 G08 G09 G11 G15

Table 6. Categorization and grouping based on flag leaf attitude

Types	Code	Genotypes
Erect	1	G01 G02 G05 G08 G09 G10 G11 G12 G13
Semi-erect	3	G03 G04 G06 G07 G14 G15
Horizontal	5	Nil
Descending	7	Nil

4.1.4 Leaf blade pubescence

On the basis of leaf blade pubescence, rice genotypes were classified as glabrous-1, intermediate-2 and pubescent-3. But there was no variation among the genotypes observed and all the genotypes were pubescent type table 7 and (Plate 1).

4.1.5 Penultimate leaf: ligule

On the basis of presence of ligule the rice genotypes were categorized as absent-1 and present-9. All the genotypes showed presence of ligule.

4.1.6 Penultimate leaf: shape of the ligule

On the basis of ligule shape, rice genotypes were classified as absent-0, truncate-1, acute to acuminate-2 and 2-cleft-3 type. But our all genotypes were 2-cleft type that means there was no significant difference among the genotypes (Table 9). According to IRRI most of the cultivated rice had 2-cleft type ligule shape and wild type genotypes showed others type. From our observation the 2-ceft type ligule was found (Plate 2).

4.1.7 Ligule color

Descriptors for wild and cultivated rice, cultivated rice were categorized into 6 groups as absent (ligule less)-0, whitish-1, yellowish green-2, purple-3, light purple-4 and purple lines-5. But only 2 types of ligule color viz. yellowish green (Plate 3) and whitish (Plate 4) were found among our 15 genotypes. Twelve genotypes (G01, G02, G03, G04, G05, G08, G09, G11, G12, G13, G14 and G15) were whitish type and rest three genotypes (G06, G07 and G10) were yellowish green type (Table 10).

Table 7. Categorization and grouping based on leaf blade pubescence

Types	Code	Genotypes
Glabrous	1	Nil
Intermediate	2	Nil
Pubescent	3	All are pubescent

Table 8. Categorization and grouping based on presence of ligule

Types	Code	Genotypes
Absent	1	Nil
Present	9	All genotypes had ligule

Table 9. Categorization and grouping based on ligule shape

Types	Code	Genotypes
Absent	0	Nil
Truncate	3	Nil
Acute to acuminate	5	Nil
2-Cleft	7	All are 2-Cleft type

Table 10. Categorization and grouping based on ligule color

Types	Code	Genotypes
Absent	0	Nil
Whitish	1	G01 G02 G03 G04 G05 G08 G09 G11 G12 G13 G14 G15
Yellowish green	2	G06 G07 G10
Purple	3	Nil
Light Purple	4	Nil

Plate 1. Pubescent leaf

Plate 2. 2-cleft type ligule

Plate 3. Whitish color ligule

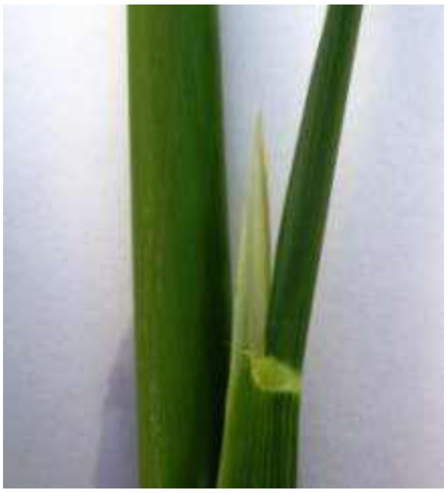


Plate 4. Yellowish green ligule

4.1.8 Color of stigma

On the basis of ligule shape, rice genotypes were classified as white-1, light green-2, yellow-3, light purple-4, purple-5. Three genotypes (G02, G06, G07) showed purple color stigma and twelve genotypes (G01, G02, G04, G05, G08, G09, G10, G11, G12, G13, G14, G15) showed white color stigma (Table 11).

4.1.9 Auricle color

According to BIODIVERSITY INTERNATIONAL IRRI AND WARDA.2007. Descriptors for wild and cultivated rice, cultivated rice were categorized into 4 groups as-absent (ligule less)-0, whitish-1, yellowish green-2, and purple-3. But only 2 types of auricle color were found among our fifteen genotypes. Ten genotypes (G01, G02, G03, G04, G05, G07, G09, G11, G12 and G13) showed whitish type auricle color and rest genotypes (G06, G08, G10, G14 and G15) showed yellowish green type auricle color (Table 12).

From Plate-7 and Plate-8 we can see whitish color auricle and yellowish green color ligule respectively.

4.1.10 Lemma and Palea: Anthocyanin coloration

On the basis of lemma and palea anthocyanin coloration the observed genotypes were grouped as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9. Only one genotype (G05) showed anthocyanin coloration. Other genotypes (G01, G02, G03, G04, G06, G07, G08, G09, G10, G11, G12, G13, G14 and G15) showed absent or very weak anthocyanin coloration (Table 13).

Table 11. Categorization and grouping based on color of stigma

Types	Code	Genotypes
White	1	G01 G03 G04 G05 G08 G09 G10 G11 G12 G13 G14 G15
Light green	2	Nil
Yellow	3	Nil
Light purple	4	Nil
purple	5	G02 G06 G07

Table 12. Categorization and grouping based on auricle color

Types	Code	Genotypes
Absent	0	Nil
Whitish	1	G01 G02 G03 G04 G05 G07 G09 G11 G12
Yellowish green	2	G06 G08 G10 G14 G15
Purple	3	Nil

Table 13. Categorization and grouping based on lemma and palea: Anthocyanin coloration

Types	Code	Genotypes
Absent or very weak	1	G01 G02 G03 G04 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15
Weak	3	Nil
Medium	5	G05
Strong	7	Nil
Very strong	9	

Plate 5. White color stigma **Plate 6. Purple color stigma**

Plate 7. Whitish color auricle **Plate 8. Yellowish white color auricle**

4.1.11 Culm habit

The estimated average angle of inclination of the base of the main culm from vertical after flowering, rice genotypes were classified as erect (<15°)-1, semi-erect (intermediate) (~20°)-3, open (~40°)-5, spreading (60-80°)-7 and procumbent -9 type. Here 5 genotypes (G05, G08, G09, G12 and G13) showed erect type and 10 genotypes (G01, G02, G03, G04, G07, G10, G11, G14 and G15) showed semi-erect type in nature but open, spreading and procumbent type culm were not found in any genotypes (Table 14). From Plate-9 and Plate-10 we can see semi-erect and erect type of culm habit respectively.

4.1.12 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 5 groups as erect (compact panicle)-1, semi-erect (semi-compact panicle)-3, spreading (open panicle)-5, horizontal-7 and drooping- 9. Here six genotypes (G02, G05, G06, G07, G08 and G10) showed horizontal type and nine genotypes (G01, G03, G04, G09, G11, G12, G13, G14 and G15) showed drooping type panicle. Erect and semi-erect type panicles were not found among the genotypes (Table 15**.** Plate-11 and Plate-12 shows horizontal type and drooping type panicle respectively.

4.1.13 Panicle: exertion

Panicle exertion means the panicle comes out from the leaf sheath of flag leaf. On the basis of the degree of exertion it was classified into 5 groups as enclosed-1, partly exerted-3, just exerted-5, moderately exerted-7 and well exerted-9. Here, one genotype (G09) was moderately exerted and fourteen genotypes (G01, G02, G03, G04, G05, G06, G07, G08, G10, G11, G12, G13, G14 and G15) were well exerted (Table 16).

Table 14. Categorization and grouping based on culm habit

Types	Code	Genotypes
Erect	1	G05 G08 G09 G12 G13
Semi-erect	3	G01 G02 G03 G04 G06 G07 G10 G11 G14 G15
Open	5	Nil
Spreading	7	Nil
Procumbent	9	Nil

Table 15. Categorization and grouping based on attitude of branches

Types	Code	Genotypes
Erect	1	Nil
Semi-erect	3	Nil
Spreading	5	Nil
Horizontal	7	G02 G05 G06 G07 G08 G10
Drooping	9	G01 G03 G04 G09 G11 G12 G13 G14 G15

Table 16. Categorization and grouping based on panicle exertion

Types	Code	Genotypes
Enclosed	1	Nil
Partly exerted	3	Nil
Just exerted	5	Nil
Moderately exerted	7	G09
Well exerted	9	G01 G02 G03 G04 G05 G06 G07 G08 G10 G11 G12 G13 G14 G15

Plate 9. Semi erect type culm

Plate 10. Erect type culm

Plate 11. Drooping type panicle

Plate 12. Horizontal type panicle

Plate 13. Moderately exerted panicle

Plate 14. Well exerted panicle

4.1.14 Grain color: lemma and palea color (seed coat color)

On the basis of lemma and palea coloration the observed genotypes were categorized as straw-1, golden-2, purple-4 and black-5. Lemma and palea combindly indicates the seed coat color actually. In this study among our observed genotypes, four genotypes (G02, G03, G04 and G06) were found straw type, and five genotypes (G01, G05, G07, G08 and G09) were golden type seed coat color (Table17). Plate 15 showing straw color grain of genotypes.

4.1.15 Color tip of lemma

According to color tip of lemma the rice genotypes were categorized as white-1, yellowish-2, brownish-3, red-4, purple-5, black -6. Three genotypes (G02, G06 and G07) showed red color tip and twelve genotypes (G01, G03, G04, G05, G08, G09, G10, G11, G12, G13, G14 and G15) showed yellowish color tip (Table 18). Plate 16 showing red color tip of lemma and Plate 17 showing yellowish color tip of lemma.

4.1.16 Presence of awn

This character was observed at maturity stage and based on presence of awns, our observed genotypes were categorized into 3 groups as absent-0, partly awned-1 and fully awned-2. Here six genotypes (G01, G02, G06, G07, G09 and G11) was fully awned and rest nine genotypes (G03, G04, G05, G08, G10, G12, G13, G14 and G15) had no awns (Table 19). Plate 18 showing fully awned grain.

Table 17. Categorization and Grouping based on grain color

Types	Code	Genotypes
Straw	1	G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15
Golden	2	Nil
Purple	4	Nil
Back	5	Nil

Table 18. Categorization and grouping based on color tip of lemma

Types	Code	Genotypes
White	1	Nil
Yellowish	2	G01 G03 G04 G05 G08 G09 G10 G11 G12 G13 G14 G15
Brownish	3	Nil
red	4	G02 G06 G07
Purple	5	Nil
Black	6	Nil

Table19. Categorization and grouping based on presence of awn

Types	**Code**	**Genotypes**
Absent	0	G03 G04 G05 G08 G12 G13 G14 G15
Partly awned	1	Nil
Fully awned	2	G01 G06 G07 G09 G11

Plate 15. Straw color grain of the genotypes

Plate 16. Red color tip of lemma

Plate 17. Yellowish color tip of lemma

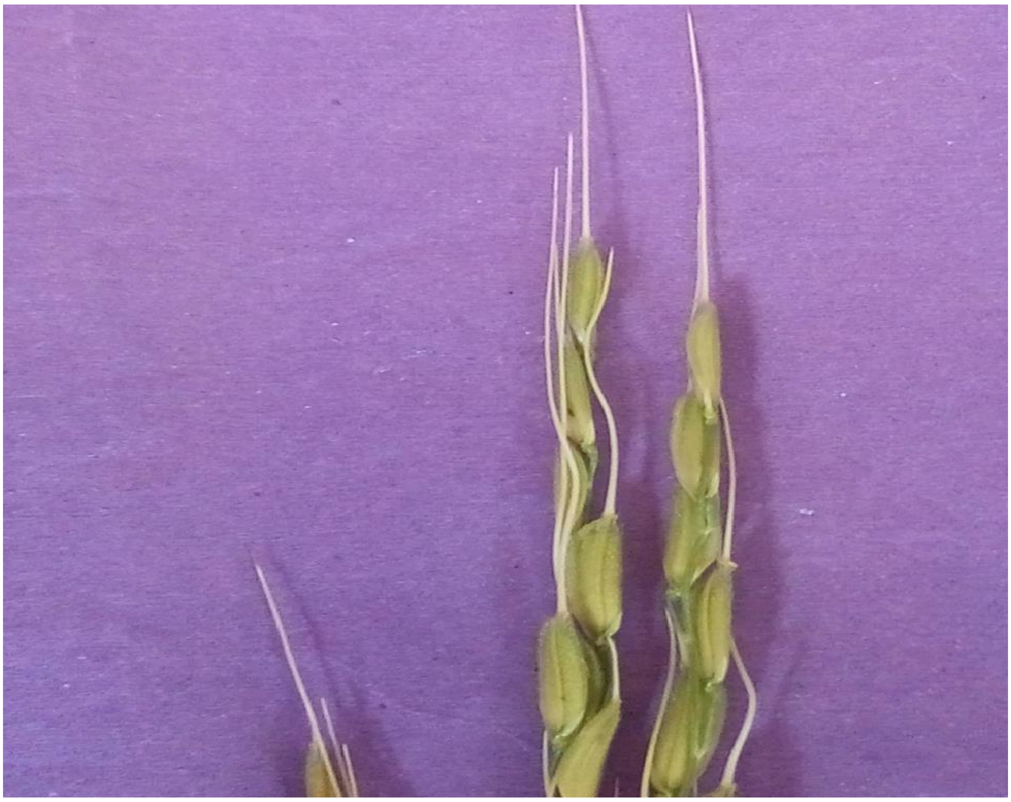


Plate 18. Fully awned grain

4.1.17 Distribution of awns

On the basis of distribution of awns the rice genotypes were categorized as Tip only-1, Upper half only-3, Whole length-5. The genotypes which had awns found tip only-1 type (Table 20).

4.1.18 Color of awns

It was observed at flowering to maturity stage and grouped as per descriptors such as yellow white-1, brown-3, reddish-5, purple-7 and black-9. In this case only two genotypes (G06 and G07) showed reddish colored awn (Table 21).

4.1.19 Leaf senescence

Data was collected at harvest stage and the rice genotypes 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. Thirteen genotypes (G01, G02, G03, G04, G05, G06, G07, G08, G09, G10, G11, G14 and G15) showed intermediate type and two genotypes were (G12 and G13) showed late and slow type of leaf senescence (Table 22).

4.1.20 Caryopsis scent

Different techniques to detect aroma were developed by several scientists around the world. I just followed the technique developed by IRRI where aroma was detected by smelling (Sensory Test) after adding l.7% (0.3035N) solution of KOH. Based on aroma our tested genotypes were categorized in 3 groups as non-scented-0, lightly scented-1, and scented-2. All the tested genotypes were found non-scented type (Table 23).

Table 20. Categorization and grouping based on distribution of awn

Types	code	Genotypes
Tip only	1	G01 G02 G06 G07 G09 G11
Upper half only	3	Nil
Whole length	5	Nil

Table 21. Categorization and grouping based on color of awns

Types	Code	Genotypes
Yellow white	1	G01 G02 G09 G11
Brown	3	Nil
Reddish	5	G06 G07
Purple	7	Nil
Black	9	Nil

Table 22. Categorization and grouping based on leaf senescence

Types	Code	Genotypes
Late and slow (2 or more leaves retain green color at maturity).	1	G12 G13
Intermediate	5	G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G14 G15
Early and fast(leaves are dead at maturity)	9	Nil

Table 23. Categorization and grouping based on caryopsis scent

Types	code	Genotypes
Non-scented	0	G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15
Lightly scented	1	Nil
Scented	2	Nil

4.2 Characterization based on quantitative characters

4.2.1 Culm length:

Culm lengths of observed lines ranged from 76.40(G04) cm to 61.67(G13) cm with a mean value of 68.932 cm (Appendix III). On the basis of this character, the genotypes were categorized into 9 groups as very short (<50 cm), very short to short (51-70 cm), short (71-90 cm), short to intermediate (91-105 cm), intermediate (106-120 cm), intermediate to long (121-140 cm, long (141-155 cm), long to very long (156-180 cm) and very long (>180 cm) as the guided descriptors where there were nine genotypes (G02, G03, G05, G06, G08, G10, G11, G12 and G13) belongs to very short to short category and six genotypes (G01, G04, G07, G09, G14 and G15) belongs to short category presented in Table-24. From the Figure-9, we can distinguish different groups of observed genotypes based on culm length where genotypes and culm length has been presented horizontal and Vertical axis, respectively.

4.2.2 Panicle length:

The panicle length was measured in cm from panicle base to the tip of the panicle of main tiller without awns. The panicle length of the observed genotypes ranged from 32.580 cm (G08) to 23.053 cm (G10) with a mean value of 26.196 cm (Appendix-III) and based on this character, the genotypes were classified into five groups as very short (<11 cm), short (12-15 cm), medium (16-25 cm), long (26-35 cm) and very long (>35 cm). From our observed genotypes we can see that eight genotypes (G01, G02, G03, G04, G05, G10, G14 and G15) were under Medium group and rest seven genotypes (G06, G07, G08, G09, G11, G12and G13) were under long group and other types of panicle were not found (Table 25). From the Figure-10 we can distinguish different groups of observed genotypes based on panicle length where genotypes and panicle length has been presented in horizontal and vertical axis, respectively.

Table 24. Categorization and grouping based on culm length

Groups	**Scale**	**Code**	**Genotypes**
Very short	<50 cm	1	Nil
Very short to short	51-70 cm	2	G02 G03 G05 G06 G08 G10 G11 G12 G13
Short	71-90cm	3	G01 G04 G07 G09 G14 G15
Short to intermediate	91-105 cm	4	Nil
Intermediate	106-120 cm	5	Nil
Intermediate to long	121-140 cm	6	Nil
Long	141- 155cm	7	Nil
Long to very long	156-180 cm	8	Nil
Very long	>180 cm	9	Nil
Range	(G13) 61.67cm - (G04) 76.40 cm		
Average	68.932 cm		

Table 25. Categorization and grouping based on panicle length

Groups	**Scale**	**Code**	**Genotypes**
Very short	<11 cm	1	Nil
Short	12-15 cm	3	Nil
Medium	16-25 cm	5	G01 G02 G03 G04 G05 G10 G14 G15
Long	26-35 cm	7	G06 G07 G08 G09 G11 G12 G13
Very long	>35 cm	9	Nil
Range	(G10) 23.053 cm - (G08) 32.580 cm		
Average	26.196 cm		

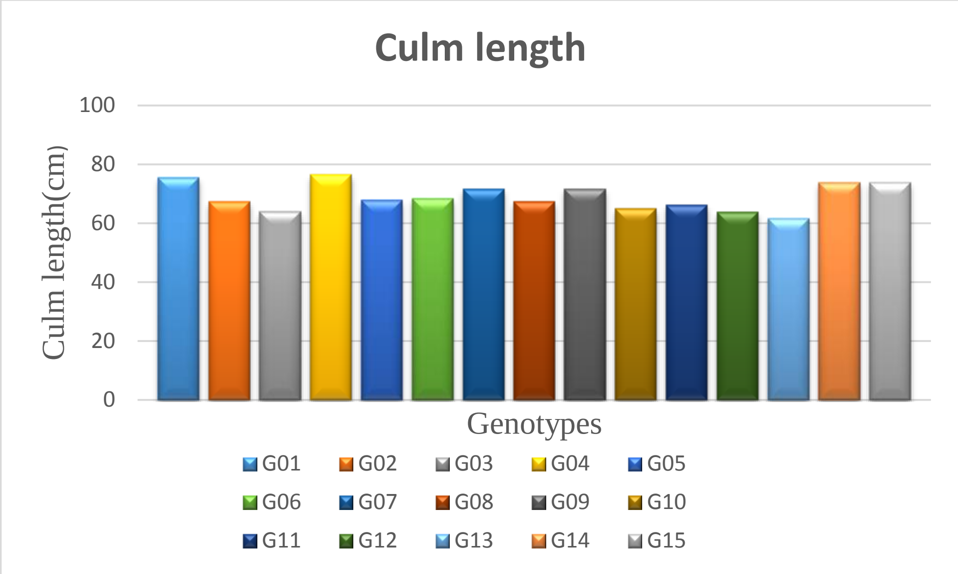


Figure 9. Different culm length (cm) up to neck of the rice genotypes

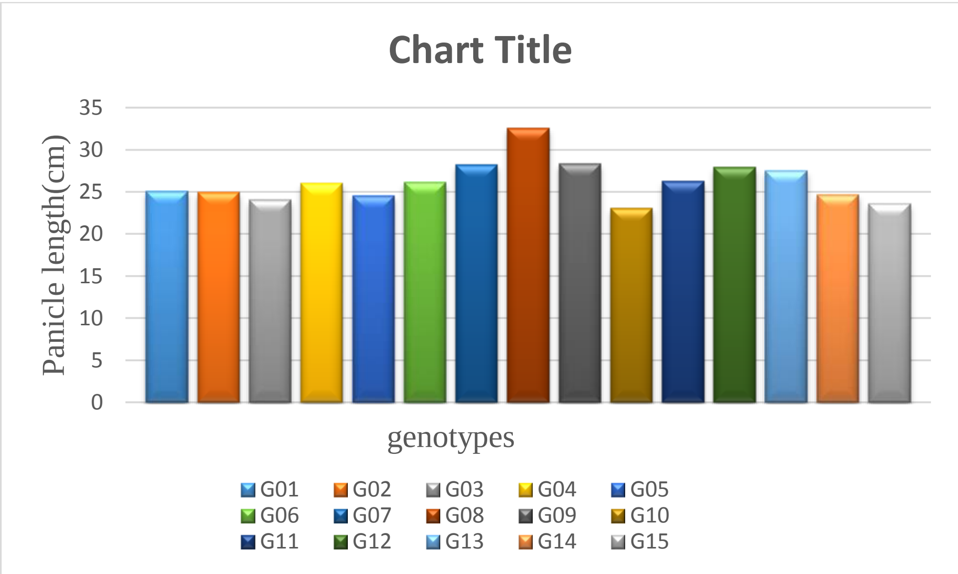


Figure 10. Different panicle length (cm) of the observed genotypes

4.2.3 Culm diameter

Culm diameter was measured from mother tillers in the lowest internode. From our observed genotypes, it was ranged from 4.15 mm (G10) to 6.54 mm (G01) with a mean value of 5.88 mm (Appendix-III). Based on this character, the observed genotypes were classified as small (<5.0 mm), medium (5.1-6.0 mm), large (6.1-7.0 mm) and very large (>7.0 mm) where eight genotypes (G01, G02, G03, G06, G07, G11, G12 and G13) belongs to large category, six genotypes (G04, G05, G08, G09, G14 and G15) belongs to medium category and only one genotype (G10) belongs to small category (Table-26).

4.2.4 Time of heading

Date on which 50% of panicle emergence is done of the rice fields known as heading. It is specified either as the number of days from seed sowing date to 50% heading date. Times of 50% heading of the observed lines ranged from 104 days to 127 days with a mean value 119.97 days (Appendix-III). On the basis of time of 50% heading, rice genotypes 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). One genotype (G10) showed medium, five genotypes (G01, G05, G07, G11 and G15) showed late and nine genotypes (G02, G03, G04, G06, G08, G09, G12, G13 and G14) showed very late but no genotypes showed early or very early type of 50% heading formation. A pictorial view of time of heading is shown in Plate 19. Figure11. Showing bar graph of time of heading of different lines.

Table 26. Categorization and grouping based on culm diameter

Groups	Scale	Code	Genotypes
Small	<5.0 mm	1	G10
Medium	5.1-6.0 mm	3	G04 G05 G08 G09 G14 G15
Large	6.1-7.0	5	G01 G02 G03 G06 G07 G11 G12 G13
Very Large	>7.0 mm	7	Nil
Range	(G07) 4.15 mm - (G02) 6.54 mm		
Average	5.88 mm		

Table 27. Categorization and grouping based on time of heading (50%)

Groups	Scale(days)	Code	Genotypes
Very early	<70	1	Nil
Early	70-85	3	Nil
medium	86-105	5	G10
Late	106-120	7	G01 G05 G07 G11 G15
Very late	>120	9	G02 G03 G04 G06 G08 G09 G12 G13 G14
Range	(G10) 104 days- (G12) 127days		
Average	119.97 Days		

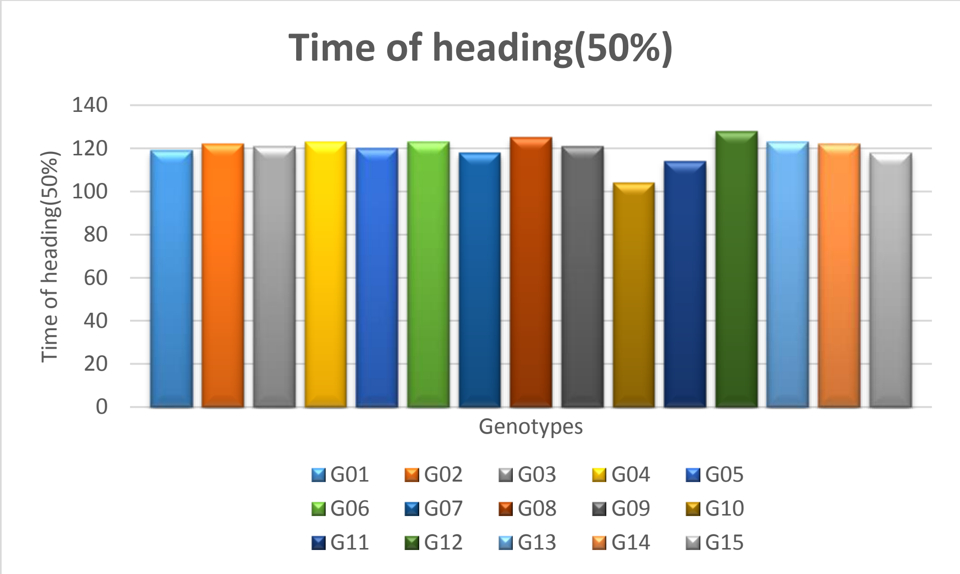


Figure 11. Different time of heading (50%) of the observed lines

Plate 19. Time of heading (50% of plants with heads)

4.2.5 Number of effective tillers per hill

The number of effective tillers per hill of the observed genotypes were ranged from 17.133 (G05) to 22.933 (G08) with a mean value of 19.089 (Table 28 and Appendix-III) and considering this character, the observed genotypes were categorized as low (<7)-3, intermediate (8- 12)-5 and high (>12)-7 effective tillers per plant. From the observed genotypes it was observed that all the genotypes belongs to high category (Table 28) and (Figure 12).

4.2.6 Thousand seed weight (dry)

Thousand grain weight of the observed genotypes were ranged from 20.933 g to 28.113 g with a mean value of 24.213 g (Appendix-III) and considering this character, the genotypes were grouped as very low (<l5 g)-1, low (l6-19 g)-3, medium (20-23 g)-5 and high (24-27 g)-7, very high (>27 g)-9. Only one genotype i.e. (G06) was recorded as very high, eight genotypes (G04, G05, G07, G08, G10, G12, G13, G14) as medium, 6 genotypes (G01, G02, G03, G09, G11 and G15) as medium type (Table 29). and (Figure 13).

Table 28. Categorization and grouping based on effective numbers of tillers per plant

Groups	Scale	Code	Genotypes
Low	<7 culms	3	Nil
Intermediate	8-12 culms	5	Nil
High	>12 culms	7	G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15
Range	(G05) 17.133- (G08) 22.933		
Average	19.089 culms		

Table 29. Categorization and grouping based on thousand seed weight

Groups	Scale	Code	Genotypes
Very Low	<15 g	1	Nil
Low	16-19 g	3	Nil
Medium	20-23 g	5	G04 G05 G07 G08 G10 G12 G13 G14
High	24-27 g	7	G01 G02 G03 G09 G11 G15
Very high	>27 g		G06
Range	(G07) 20.933 - (G06) 28.113 g		
Average	24.082 g		

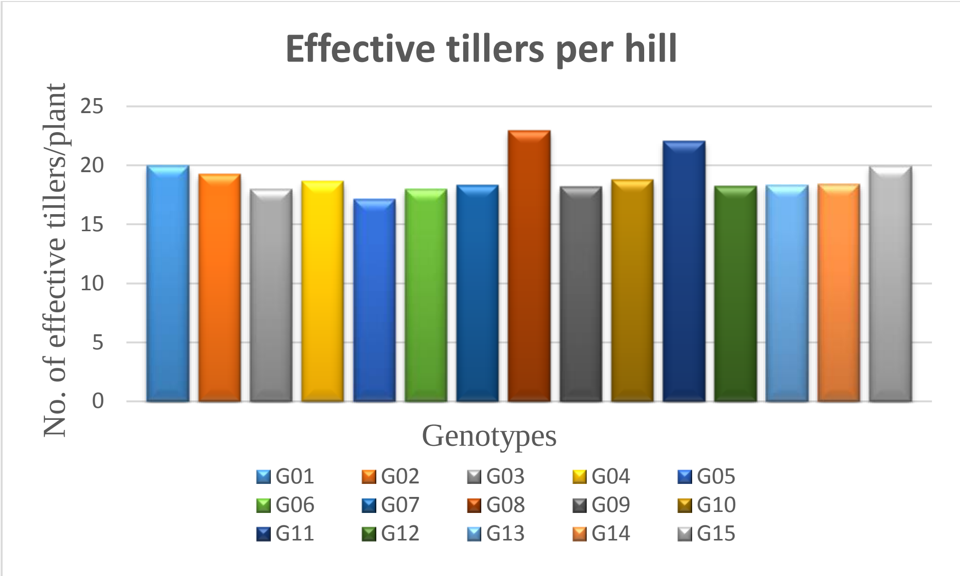


Figure 12. Different effective tillers per hill of observed genotypes

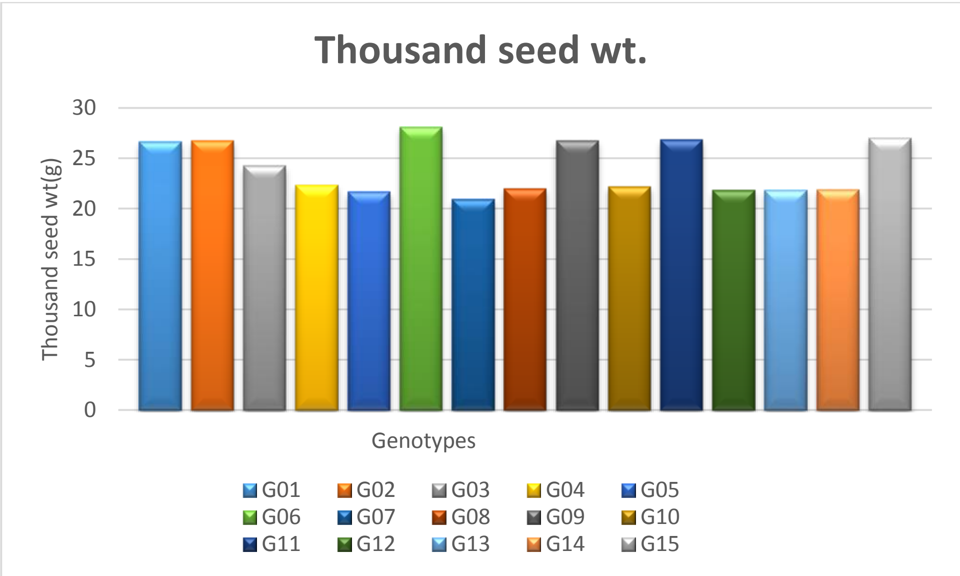


Figure 13. Different thousand seed weight of the observed genotypes

4.2.7 Time of maturity

Time of maturity of the observed genotypes ranged from 151 days (G08) to 130 days (G10) with a mean value of 142.87 days (Appendix-III) and on the basis of this character, all the genotypes were classified into 4 groups as very early (<100 days)-1, early (101-115 days)-3, medium (116-135days)-5, late (136-150)-7 and very late (>150 days)-9. Here two genotypes (G10 and G11) was recorded as Medium, two genotypes (G01, GO2, G03, G04, G05, G06, G07, G09, G13, G14 and G15) as late and two genotypes (G08 and G12) as very late group (Table 30).This grouping based on days to maturity is also shown in bar graph for more easy perception by the following Figure-14, where genotypes had been shown in vertical axis and days to maturity along the horizontal axis.

4.2.8 Grain length

Grain length of 30 aromatic rice genotypes ranged from 9.79 mm to 8.44 mm with a mean value of 9.13 mm (Appendix-III). On the basis of grain length, the observed genotypes were grouped as short (<5.50 mm), medium (5.51-6.5mm), long (6.51-7.5 mm) and extra-long (>7.51 mm). All the genotypes (G01, G02, G03, G04, G05, G06, G07, G08, G09, G10, G11, G12, G13, G14 and G15) were found extra-long type (Table 31). No genotypes were found as short type. Figure 15 showing different grain length of the genotypes.

Table 30. Categorization and grouping based on time of maturity

Groups	Scale (Days)	Code	Genotypes
Very early	<100	1	Nil
Early	101-115	3	Nil
Medium	116-135	5	G10 G11
Late	136-150	7	G01 G02 G03 G04 G05 G06 G07 G09 G13 G14 G15
Very Late	>150	9	G08 G12
Range	(G10) 130 Days - (G08) 151 days		
Average	142.87 days		

Table 31. Categorization and grouping based on grain length

Groups	Scale	Code	Genotypes
Short	<5.5 mm	1	Nil
Medium	5.51-6.5 mm	3	Nil
Long	6.51-7.5 mm	5	Nil
Extra Long	>7.51 mm	7	G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15
Range	(G10) 8.44 - (G12) 9.79 mm		
Average	9.13 mm		

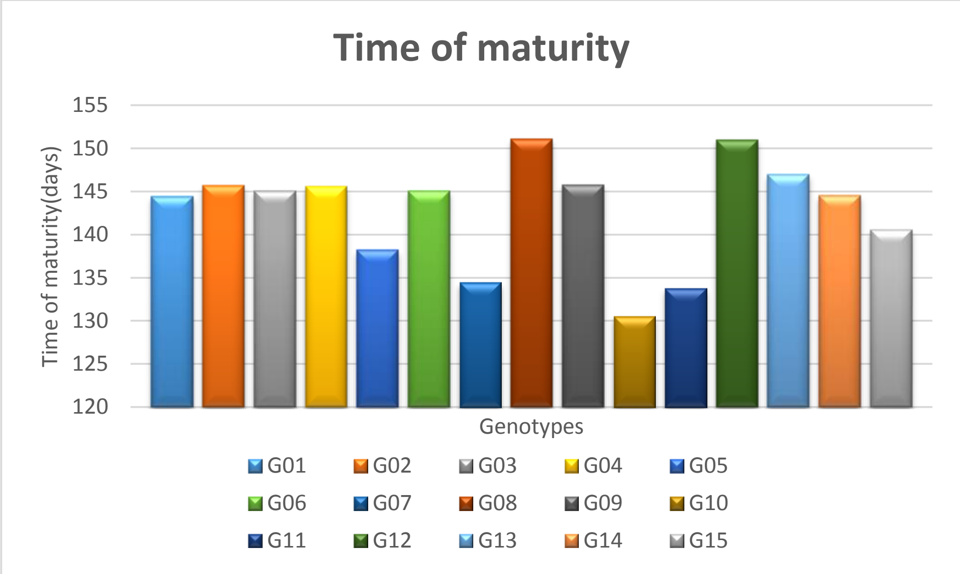


Figure 14. Different time of maturity of the observed genotypes

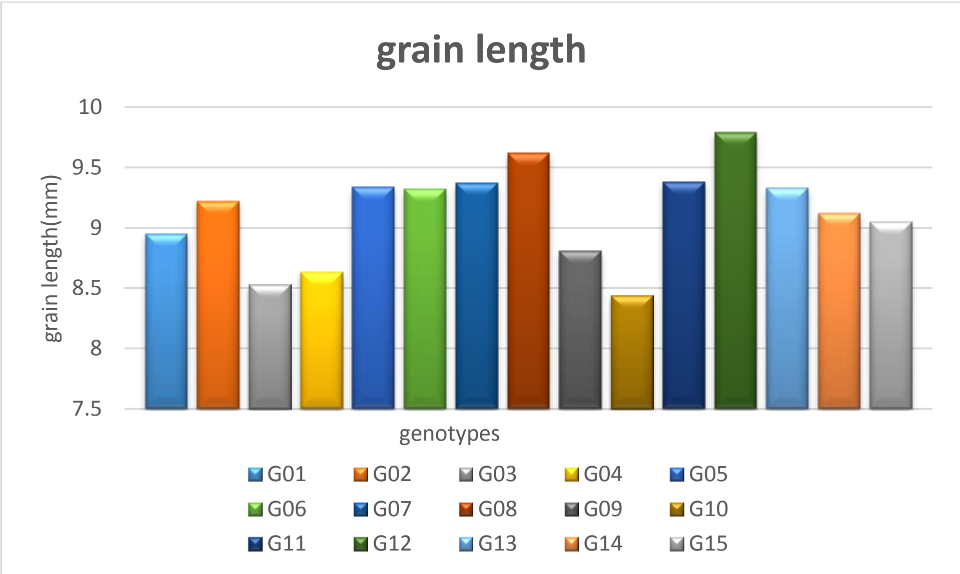


Figure 15. Different grain length of the observed genotypes

4.2.9 Grain width

On the basis of grain width our observed genotypes were categorized as fine (<2.5 mm)-3, medium (2.51-3 mm)-5 and coarse (>3 mm)-7. Grain width ranged from 2.37 mm to 3.26 mm with a mean value of 2.75 mm (Appendix-III). Two genotypes (G11 and G15) were coarse, eleven genotypes (G01, G02, G03, G05, G06, G07, G08, G09, G12, G13 and G14) were medium type and rest 2 genotypes (G04 and G10) were fine (Table 32). Figure 16 showing different grain width of the genotypes.

4.2.10 Yield per square meter

Yield per plant ranged from 629.52 g (G07) to 850.02 g (G06) with a mean value of 752.34 g (Appendix III). On the basis of seed yield per plant the observed genotypes were grouped as low (>450gm)-1, medium (450-650gm)-3 and high (>650gm)-5 seed yielder where only one genotype (G05) was recorded as medium category and rest eight genotypes (G01, G02, G03, G04, G06, G07, G08, G09, G10, G11, G12, G13, G14 and G15) were as high category (Table 33).

This grouping based on yield per square meter area is also shown in graph for more easy understanding by the following Figure-17, where genotypes have been shown horizontal axis and yield per square meter area along the vertical axis.

Table 32. Categorization and grouping based on grain width

Groups	Scale	Code	Genotypes
Fine	<2.5 mm	3	G04 G10
Medium	2.51-3 mm	5	G01 G02 G03 G05 G06 G07 G08 G09 G12 G13 G14
Coarse	>3 mm	7	G11 G15
Range	(G04) 2.37mm - (G11) 3.26 mm		
Average	2.75 mm		

Table 33. Categorization and grouping based on yield per square meter

Groups	Scale (g)	code	genotypes
Low	<450	1	Nil
medium	450-650	3	G05
High	>650	5	G01 G02 G03 G04 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15
Range	(G05) 580.22g – (G01) 964.64g		
Average	829.49 g		

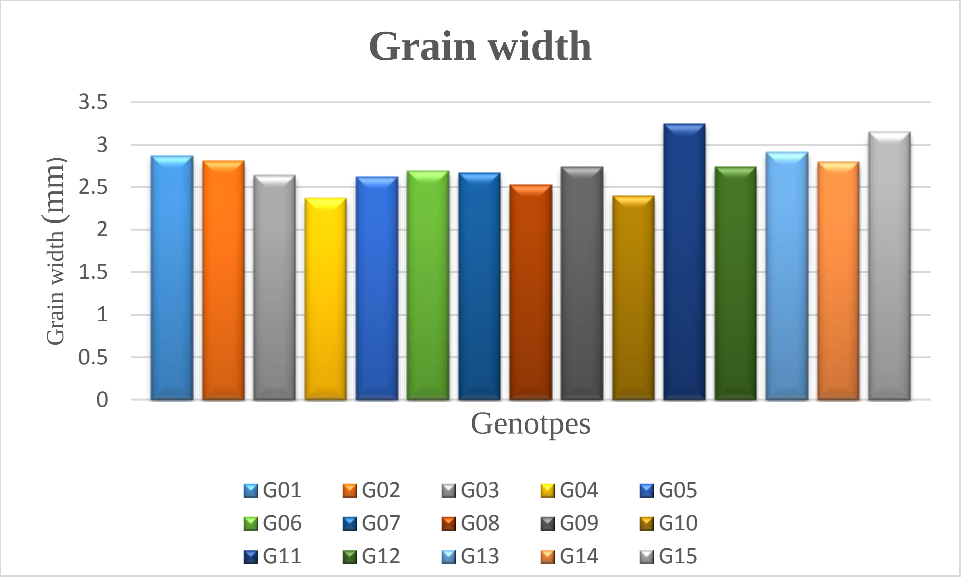


Figure 16. Different grain width of observed genotypes

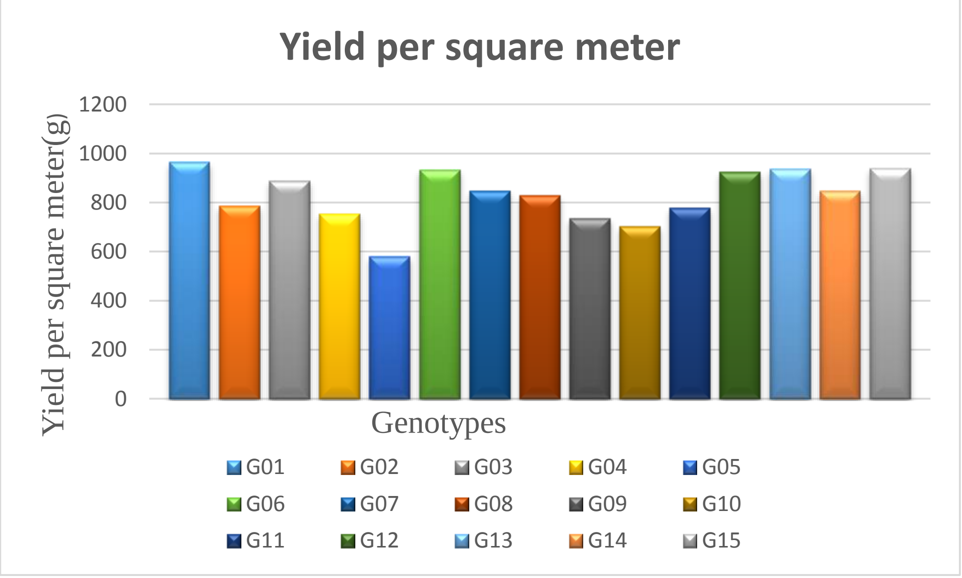


Figure 17. Different yield per square meter of the observed lines

4.3 Variability Study

Genetic variability among traits is important for breeding and in selecting desirable types. The available variability in a population can be partitioned into genetic parameter such as genotypic variation, phenotypic variation, and environmental variation; PCV, GCV and ECV to serve as the basis for selection of desirable lines than existing ones.

4.3.1 Plant height (cm)

The analysis of variance indicated significant difference among rice lines (107.061), studied for plant height at 5% level of probability (Appendix II). The highest plant height was observed in G04 (112.06 cm) followed by G09 (100.07 cm) .The lowest plant height was observed in G10 (87.58 cm). The mean value of plant height was 94.903 cm (Table-34) and heritability 96.31 (Appendix IV). Plant height showed high heritability. Phenotypic variance (36.587) and genotypic variance (35.237) was relatively low differences between them which indicating lower environmental influences on this trait (Table-35). Value of PCV and GCVwere 6.37 and 6.25.The minimal difference between PCV and GCV indicated the genetic variation was minimal among the genotypic variation and environment had low influence on this character expression. Figure 18 showing variation in plant height of different lines. Figure 25 showing genotypic, phenotypic and environmental variability of the boro rice lines with their check varieties for plant height. According to Ookawa *et al.* (2010) and Chen *et al.* (2005) plant height at the heading stage have been considered important traits in breeding both super rice and bioenergy crops.

4.3.2 No. of effective tillers per plant

Analysis of variance for effective no. of tillers per plant exhibited significant (7.44) mean sum of square due to lines difference (Appendix II). The highest number of total effective tillers per plant was observed in G08 (22.93) followed by G11 (22.067). The lowest number of total effective tillers per plant was observed in G05 (17.133) and mean value was 19.089 (Table 34). Number of total effective tillers per plant showed phenotypic variance (2.61) and genotypic variance (2.41) with relatively low differences between them which indicating lower environmental influences on this trait (table 35).

Table 34: Maximum, minimum, mean and CV of parameters of boro rice lines

Parameters	Minimum	Maximum	Mean	CV (%)
PH	87.580	112.06	94.903	1.22
ETP	17.133	22.933	19.089	2.34
PL	23.053	32.580	26.196	1.60
PBP	11	14.667	12.87	3.09
SBP	48.113	59.400	52.744	1.57
FLP	143.4	211.8	189.65	1.08
UFLP	10.4	16.467	12.861	10.68
TSW	20.933	28.113	24.082	1.10
GL	8.442	9.793	9.13	0.71
YSM	580.22	964.64	829.49	0.16
DM	130.56	151.11	142.87	0.38
YH	6.15	9.916	8.422	0.24

PH = Plant height (cm), ETP = Effective tiller per plant, PL = Panicle length, PBP = Primary branch per panicle, SBP = Secondary branch per panicle, FLP = Filled grain per plant, UFLP = Unfilled grain per plant, TSW = Thousand Seed Weight, GL= Grain length (mm), YSM = Yield per square meter (L), DM = Days to maturity, YH = Yield per ha (t)

Table 35. Estimation of genetic parameters of different characters of the rice genotypes

Parameters	p	g	e	PCV	GCV	ECV
Plant height (cm)	36.587	35.237	1.350	6.37	6.25	1.22
Number of effective tiller per plant	2.61	2.41	0.19972	8.46	8.13	2.34
Panicle length	6.087	5.911	0.1762	9.41	9.28	1.60
Number of primary branch per panicle	1.08	0.92	0.15819	8.07	7.45	3.09
Number of secondary branch per panicle	15.20	14.52	0.6822	7.39	7.22	1.56
Filled grain of main tiller	387.66	383.44	4.22	10.38	10.32	1.08
Unfilled grain of main tiller	3.51	1.62	1.887	14.57	9.9	10.67
Thousand seed weight (g)	6.89	6.82	0.0701	10.9	10.84	1.09
Grain length (mm)	0.16	0.15	0.00418	4.38	4.24	0.70
Yield per square meter (g)	11551.6	11549.8	1.8	12.96	12.95	0.16
Days to maturity	37.61	37.32	0.291	4.29	4.27	0.38
Yield per ha (t)	1.08	1.07	0.00042	12.33	12.28	0.24

P = Phenotypic variance, g = Genotypic variance, and e = environmental variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, ECV = Environmental coefficient of variation

Figure 18. Significant variation for plant height (cm) of the genotypes

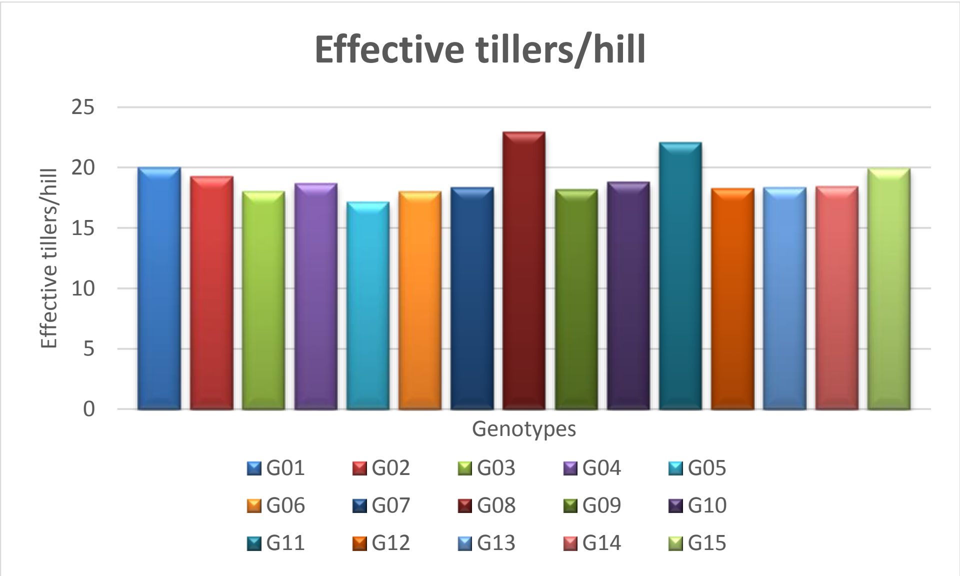


Figure 19. Significant variation for effective tillers per hill of the genotypes

Values of PCV and GCV were 8.46 and 8.13 respectively (Table 35). The low difference between PCV and GCV indicated that the genetic variation was low among the genotypic variation and environment had low influence on this character expression. Heritability was 92.33 (Appendix IV) which indicates this character was least influenced by environment. Selection for improvement of such character may be useful. Figure 24 showing genotypic, phenotypic and environmental variability of thirteen genotypes of boro rice with their check varieties for no. of effective tillers per plant. Hasanuzzaman *et al.* (2008) reported that the number of effective tillers rests on the number of tillers produced and this was directly proportional to the panicles produced per unit area and finally depends on variety. Figure 19 showing significant variation for effective tillers/hill.

4.3.3 Panicle length (cm)

Analysis of variance for panicle length (cm) exhibited non-significant mean sum of square (17.9098) (Appendix II). The panicle length (cm) was observed highest in G08 (32.580) followed by G09 (28.327). The lowest panicle length (23.053) was observed in G10 and the mean value for the trait was 26.196 cm (Table 34). The panicle length (cm) showed phenotypic variance (6.09) and genotypic variance (5.91) with relatively minimal differences between them which indicating much lower genetic influences on this trait (Table 35). Values of PCV, GCV and H^2 were 9.41, 9.28 and 97.11 respectively (Table 35) and (Appendix IV). The lower difference between PCV and GCV and high heritability indicated that the genetic variation was minimal among the genotypic variation and environment had minimal influence on his character expression. Figure 24. showing genotypic, phenotypic and environmental variability in thirteen genotypes of boro rice with their check varieties for panicle length (cm). Murthy *et al*. (2014) revealed that there were strong positive correlations of panicle length with number of spikelets per panicle, 100 seeds weight and yield per plant.

4.3.4 Number of primary branches per panicle

Analysis of variance for primary branch per panicle exhibited non-significant mean sum of square (2.93) (Appendix II). Among these observed lines the highest number of primary branches per panicle was taken in case of G11 (14.67) followed by G8 (14.13). The lowest number of primary branches per panicle was taken in G10 (11) which was close to G05 (11.40). The mean value for this trait was 12.87 (Table 34). Phenotypic variance and genotypic variance and heritability were calculated as (1.08) and (0.92) and 85.19 respectively (Table 35) and (Appendix IV). The phenotypic variance appeared to be slightly higher than the genotypic variance indicating a little influence of environment on the expression of the genes controlling this trait and relatively low difference between PCV (8.07) and GCV (7.45) value suggested that the apparent variation not only due to lines but also due to the influence of environment (Table 35).. Figure 20 showing non-significant variation in primary branches per panicle of different genotypes. Karim et al. (2007) observed higher differences between GCV and PCV for this character. Figure 20 showing variation in primary branch per panicle of different lines. Figure 24 showing genotypic, phenotypic and environmental variability of thirteen genotypes of boro rice with their check varieties for number of primary branches per panicle

4.3.5 Number of secondary branches per panicle

Number of secondary branches per panicle exhibited significant mean sum of square (44.2316) (Appendix-II), the highest number of secondary branches per panicle was observed in G08 (59.40) followed by G11 (59.00). The lowest number of secondary panicle was observed in G10 (48.133) and the mean value for this trait was 52.744 (Table 34). The phenotypic, genotypic variance and heritability for this number of secondary branches per panicle were (15.20), (14.52) and 95.53 respectively (Table 35). The lower difference between PCV and GCV and high heritability suggested that minimal influence of environment on the expression of the genes controlling this trait and selection for improvement for such character may be useful. The value of PCV and GCV were (7.39) and (7.22) respectively for number of secondary branches per panicle which denoted that low variation existed among these lines (Table 35). Figure 21 showing variation in secondary branch per panicle of different lines. Figure 24 showing genotypic, phenotypic and environmental variability of thirteen boro rice with their check varieties for number of secondary branches per panicle.

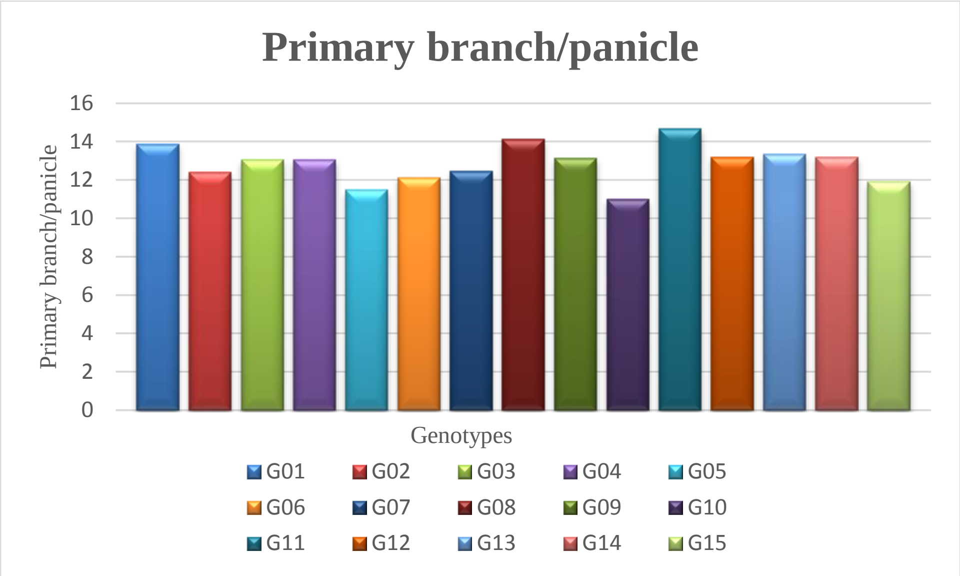


Figure 20. Non-significant variation for primary branch per panicle of the genotypes

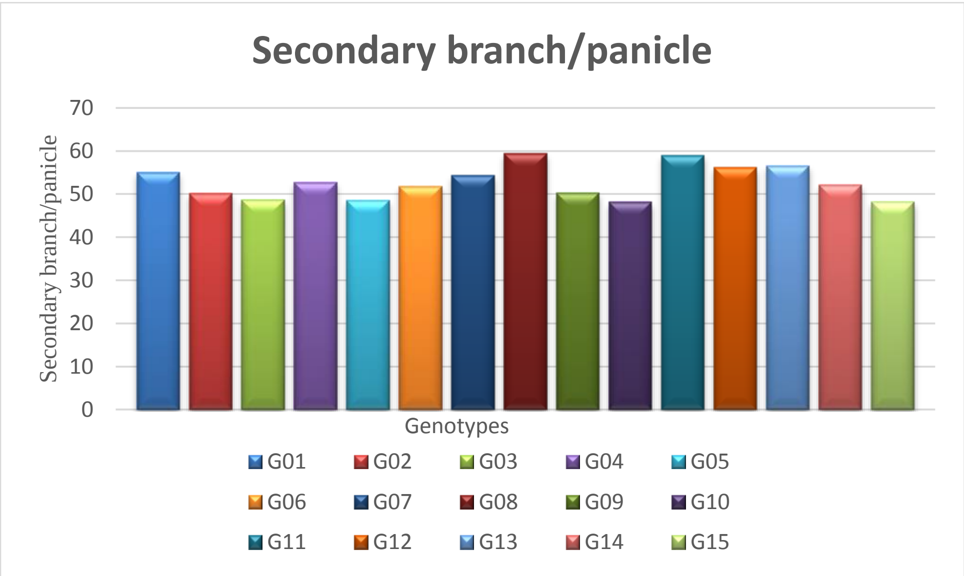


Figure 21. Significant variation for secondary branch per panicle of the observed genotypes

4.3.6 Number of filled grains per panicle

Number of filled grains per panicle exhibited highly significant mean sum of square (1154.53) due to lines difference (Appendix-II). The maximum number of filled grains per panicle was found in G01 and it was 211.8 followed by G11 (207.53) and the minimum number of filled grains per panicle was recorded in G05 and that was (143.40). The mean value for this trait was 189.65 (Table 34). The phenotypic and genotypic variances for the number of filled grains per panicle were (387.66) and (383.44), respectively (Table 35). The phenotypic variance was higher than the genotypic variance suggested that moderate influence of environment on the expression of the genes controlling this character. The value of PCV, GCV and H^2 were (10.38), (10.32) and 98.91 (Appendix IV) respectively for number of filled grains per panicle which denoted that minimal variation existed among the difference rice lines (Table 35). Figure 22 showing variation in filled grain per panicle of different lines. Figure 25 showing genotypic, phenotypic and environmental variability in thirteen advanced lines of boro rice with their check varieties for number of filled grains per panicle. Akhter *et al*. (2001) reported that Paddy yield had significant positive correlation with number of grains per panicle and 1000 grain weight.

4.3.7 Number of unfilled grains per panicle

Number of unfilled grains per panicle exhibited highly significant mean sum of square (6.76) due to lines difference (Appendix II). The maximum number of unfilled grains per panicle was found in G09 and it was 16.47 followed by G15 (14.387) and the minimum number of unfilled grains per panicle was recorded in G10 and that was (10.4). The mean value for this trait was 12.861 (Table 34). The phenotypic and genotypic variances for the number of unfilled grains per panicle were (3.51) and (1.62), respectively (Table 35). The phenotypic variance was higher than the genotypic variance suggested that moderate influence of environment on the expression of the genes controlling this character. The value of PCV and GCV were (14.57) and (9.9), respectively for number of unfilled grains per panicle which denoted that moderate variation existed among the difference rice lines (Table 35). Figure 23 showing variation in unfilled grain per panicle of different lines. Figure 26 showing genotypic, phenotypic and environmental variability in thirteen advanced lines of boro rice with their check varieties for number of unfilled.

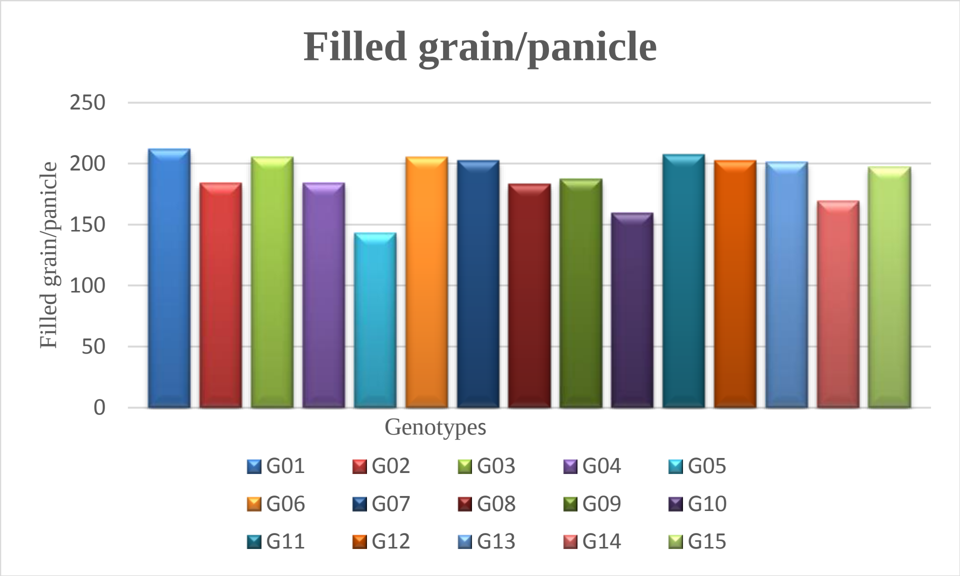


Figure 22. Significant variation for filled grain per panicle of the genotypes

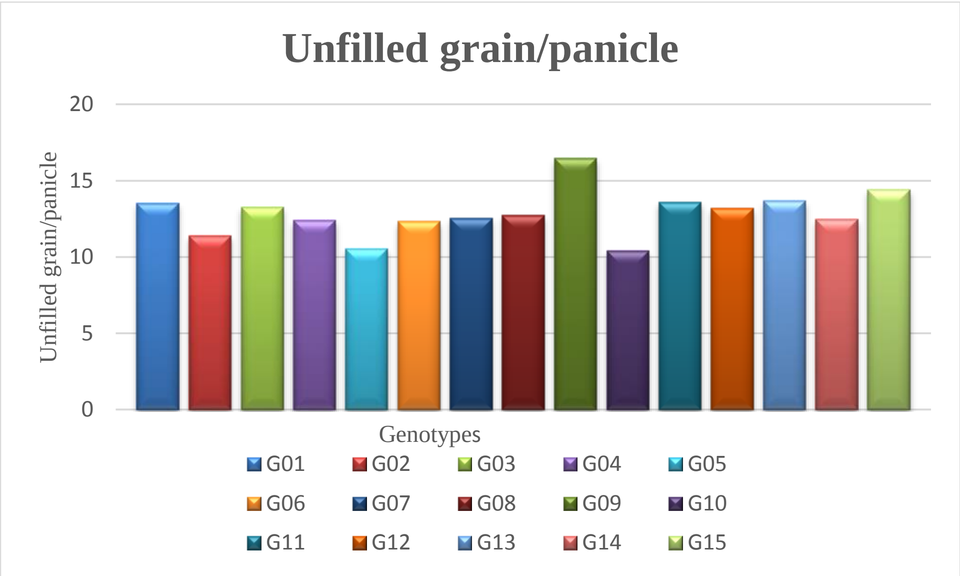


Figure 23. Significant variation for unfilled grain per panicle of the genotypes

grains per panicle. Figure 27 showing variation in unfilled grain per panicle of different lines

4.3.8 Thousand seed weight (g)

Thousand seed weight exhibited highly significant mean sum of square (20.52) due to lines difference (Appendix-II). The maximum 1000 seed weight was found in G06 and it was 28.11 g followed by G15 (27.185g) and the minimum number of 1000 seed weight was recorded in G07 and that was (20.933g). The mean value for this trait was 24.082 (Table 34). The phenotypic and genotypic variances for the 1000 seed weight were (6.89) and (6.82), respectively (Table 35). There were less difference between phenotypic variance and genotypic variance suggested that low influence of environment on the expression of the genes controlling this character. The value of PCV and GCV were (10.9) and (10.8), respectively for 1000 seed weight which denoted that lower variation existed among the difference rice lines (Table 35). Figure 24 showing genotypic, phenotypic and environmental variability in thirteen advanced lines of boro rice with their check varieties for 1000 seed weight (g). Aidei and Beighly (2006) reported that cultivation methods didn’t have much effect on 1000-grain weight.

4.3.9 Grain length (mm)

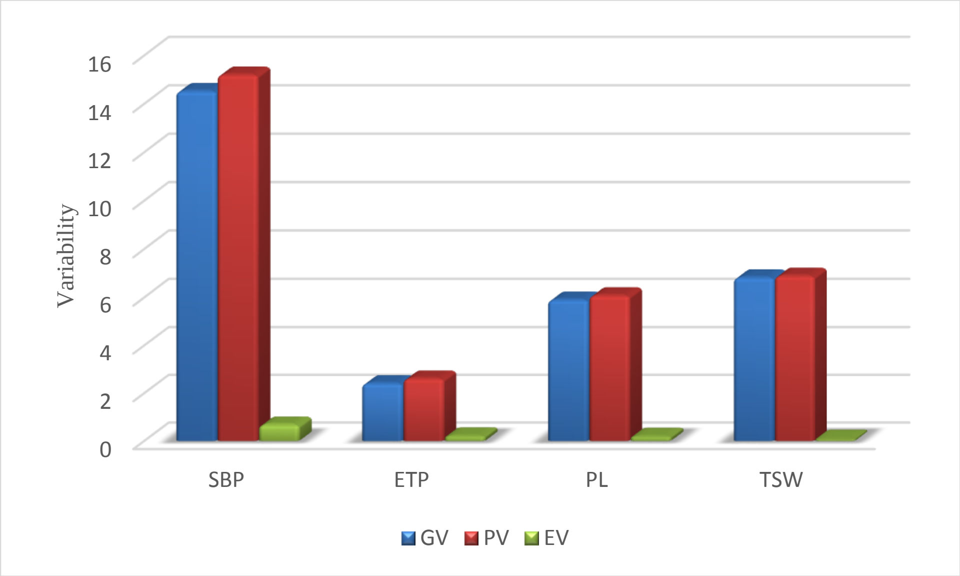
Grain length (mm) exhibited mean sum of square (0.46) due to lines difference (Appendix II). The highest grain length (mm) was found in G12 (9.79 mm) followed by G08 (9.62 mm). The lowest grain length was observed G10 (8.45 mm) followed by G03 (8.53 mm). The mean value of this trait was 9.13. The GV and PV for the grain length were (0.16) and (0.15), respectively (Table 35). There were less difference between phenotypic variance and genotypic variance suggested that low influence of environment on the expression of the genes controlling this character. The value of PCV, GCV and H^2 were (4.38), (4.24) and (93.75) respectively for 1000 seed weight which denoted that lower variation existed among the difference rice genotypes (Table 35) and (Appendix IV). High heritability showed that this character is least influenced by environment. Selection for improvement for such charcter may be useful.

4.3.10 Days of 80% maturity

Days of 80% maturity exhibited highly significant mean sum of square (112.250) due to lines difference (Appendix II). The highest days of maturity was found in G08 and it was 151.11 followed by G12 (151). The lowest days of maturity was recorded in G10 and that was (130.56) followed by G11 (133.78). The mean value of this trait was 142.87 (Table 34). Phenotypic variance and genotypic variance were measured as (37.61) and (37.32), respectively (Table 35). The difference between phenotypic variance and genotypic variance is low indicating lower influence of environment on the expression of the genes controlling this trait and relatively little difference between PCV (4.29) and GCV (4.27) value indicated that the apparent variation not only due to lines but also due to the influence of environment (Table 35). So there was a possibility for selection. Figure 25 showing genotypic, phenotypic and environmental variability of ten lines of fine grain boro rice with their check varieties for days of 80% maturity. Murthy *et al.* (2014) revealed that there was a significant and positive co-relation of grain yield per plant with days of flowering, days of maturity and leaf length.

4.3.11 Yield per square meter (g)

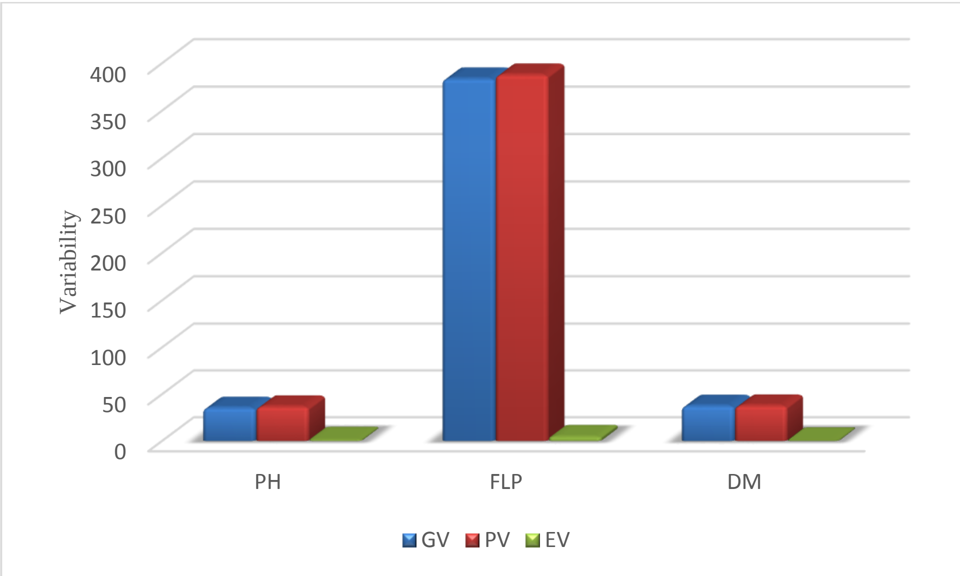
Yield per square meter exhibited significant mean sum of square (34651.2) due to lines difference (Appendix II). The highest yield per square meter (g) was found in G01 and it was 964.64 g followed by G15 (939.01), G13 (936.03) and G06 (932.32). The lowest yield per plant (g) was recorded in G05 and that was (580.22) followed by G10 (703.23) (Table 34). Phenotypic variance and genotypic variance were measured as (11551.6) and (11549.8), respectively (Table 35). The phenotypic variance observed to be moderately higher than the genotypic variance indicating moderate influence of environment on the expression of the genes controlling this trait. Relatively little difference between PCV (12.96) and GCV (12.95) value indicated that the apparent variation not only due to the influence of environment (Table 35). So there was a possibility for selection. Figure 26 showing genotypic, phenotypic and environmental variability of thirteen genotypes boro rice with their check varieties for



SBP=secondary branch per panicle, ETP= effective tillers per hill,

PL=panicle length, TSW=thousand seed weight

Figure 24. Genotypic, Phenotypic and Environmental variability in thirteen advanced lines of boro rice with check varieties



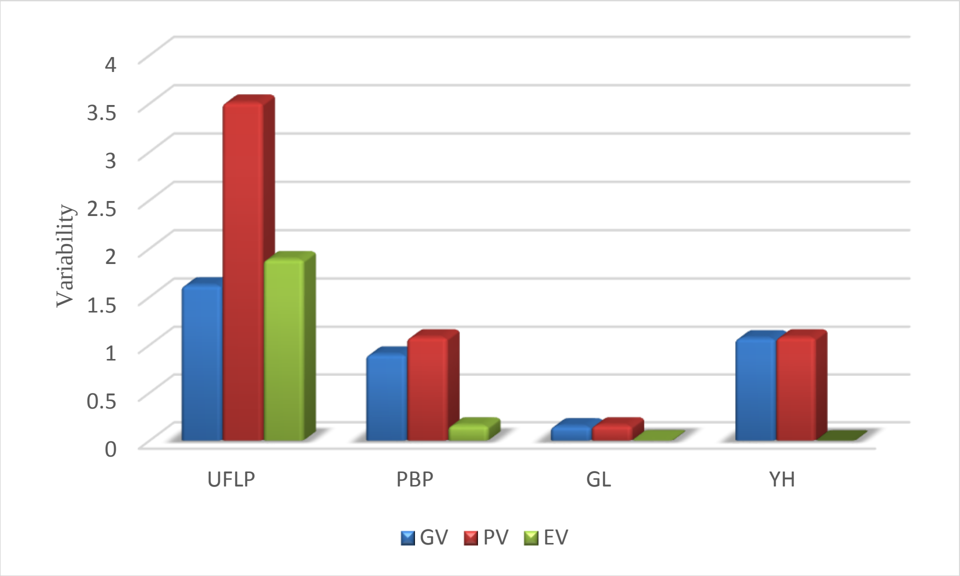
PH=plant height, FLP=filled grain per panicle, DM=days of maturity

Figure 25. Genotypic, Phenotypic and Environmental variability in thirteen advanced lines of boro rice with check varieties

yield per square meter (g). Yoshida (1981) found that improvement of rice grain yield was the main target of breeding program to develop rice varieties.

4.3.12 Yield (t/ha)

Yield exhibited significant mean sum of square (3.23) due to lines difference (Appendix II). The highest yield was found in G01 and it was 9.92 ton followed by G13 (9.37 ton), G06 (9.32 ton) and G12 (9 ton) comparing with the checks G14 (9.50 ton) and G15 (9.21 ton). The lowest yield was recorded in G05 and that was (6.15 ton) followed by G10 (7.13 ton) (Table 34). Phenotypic variance, genotypic variance and heritability were measured as (1.08), (1.07) and (99.07) respectively (Table 35) and (Appendix IV). High heritability and phenotypic variance were observed close to the genotypic variance indicating minimal influence of environment on the expression of the genes controlling this trait. Relatively little difference between PCV (12.33) and GCV (12.28) value indicated that the apparent variation not only due to the influence of environment (Table 35). So there was a possibility for selection. Figure 26 showing genotypic, phenotypic and environmental variability of thirteen genotypes of boro rice with their check varieties for yield per ha (t). Sadeghi (2011) observed positive significant association of grain yield with grains per panicle, days to maturity, number of productive tillers and days to flowering. Figure 27 showing variation in yield per ha of different lines.



UFLP=unfilled grain per panicle, PBP=primary branch per panicle,

GL=grain length, YH=yield per ha

Figure 26. Genotypic, Phenotypic and Environmental variability in thirteen advanced lines of boro rice with check varieties

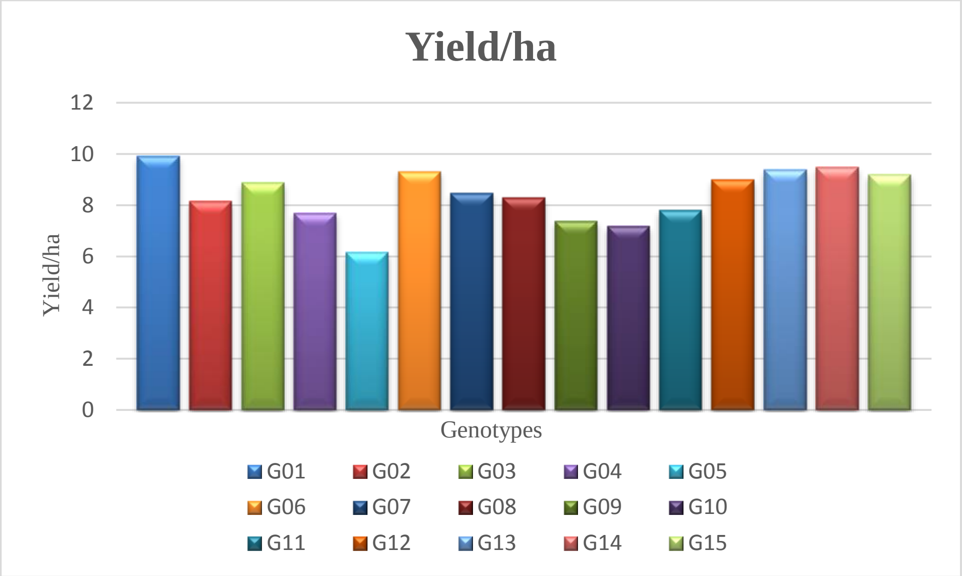


Figure 27. Significant variation for yield per ha (t) of the observed genotypes

CHAPTER V

SUMMARY AND CONCLUSION

A research work was carried out at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for characterization and variability study among thirteen genotypes of boro rice during the period of boro season in 2018-19. The genotypes were evaluated for twenty qualitative and ten quantitative traits of morphological and twelve parameters were used for variability study.

The rice lines were classified based on qualitative and quantitative traits of morphological characters developed by biodiversity International, IRRI and WARDA-(2007) for DUS test of inbreed rice. All the lines were grouped and classified as well as described based on qualitative and quantitative characters as per descriptors so that all the observed lines could be differentiated by one or more characters and identified at a glance.

All the lines showed variation for twelve qualitative characters viz. green color intensity of leaf blade, flag leaf: attitude of the blade, lemma and palea: anthocyanin coloration, spikelet: color of the tip of lemma, panicle exertion, panicle: awns in the spikelet, attitude of branches culm habit, color of the stigma, ligule color, panicle exertion, leaf senescence, color of awns. No variation was observed in these lines for eight qualitative characters viz. penultimate leaf: shape of the ligule, presence of ligule, distribution of awn, auricle color, leaf blade pubescent, basal leaf sheath color, grain color, caryopsis scent.

Ten quantitative characters viz. culm length (cm), panicle length (cm), culm diameter, time of heading (50 % of the plants with head), effective tillers per hill, thousand seed weight (g), days to maturity, grain length (mm), grain width (mm) and yield per square meter(g) showed variation among the rice lines.

In case of variability analysis ten parameters showed significant result viz. plant height (cm), no. of effective tillers per hill, panicle length (cm), number of secondary branches per panicle, number of filled grains per panicle, number of unfilled grains per panicle, thousand seed weight (g), days of 80 % maturity, yield per square meter (g) and yield per ha (t). Two parameters showed non-significant result viz. primary branch per panicle and grain length (mm).

The following characters such as leaf color, panicle: attitude of the leaf blade, panicle: curvature of main axis, panicle: exertion, plant height (cm), secondary branch per panicle, filled grains per plant, unfilled grains per plant, yield per square meter (g), stem length (cm), days to maturity (80%), grain length and yield per ha (t) were the important characters for selection of better rice lines. In case of panicle: attitude of leaf blade nine genotypes (G01, G02, G05, G08, G09, G10, G11, G12, G13) showed erect type leaf blade and six genotypes (G03, G04, G06, G07, G14, G15) showed semi-erect type leaf blade. Panicle length is one of the most important yield contributing character of rice. Panicle length of observed lines ranged from (G08) 32.58 to (G10) 23.053 cm with a mean value of 26.2 cm where eight genotypes showed medium panicle length (G01, G02, G03, G04, G05, G10, G14 and G15) and seven genotypes (G06, G07, G08, G09, G11, G12 and G13) showed long panicle length. Culm length of observed lines ranged from (G04) 76.4 cm to (G13) 61.67 cm with a mean value of 68.932 cm. In case of days of maturity two genotypes (G10 and G11) showed medium maturity date. (G01, G02, G03, G04, G05, G06, G07, G09, G13, G14 and G15) genotypes showed late in maturity (136-150 days) and (G08 and G12) showed very late (>150 days) in maturity with an average of 142.87 days.

In case of variability study total no. of secondary branch per panicle showed significant variation. The maximum no. of secondary branch per panicle was 59.4 recorded in G08 followed by G11 (59). The phenotypic and genotypic variance were 15.20 and 14.52, respectively which showed that minimal influence of environment on the expression of the genes controlling this traits. The filled grains per panicle was highly significant where G01 showed highest filled grains per panicle and it was 211.8. The phenotypic and genotypic variance were 387.66 and 383.44 respectively which showed that the moderate influence of environment on the expression of the genes controlling this traits. Significant result was obtained in yield per square meter (g) in case of variability where highest yield per plant was observed in G01 (964.64g) followed by G13 (936.03g), G06 (932.32g) and G12 (923.28g) here the difference between phenotypic and genotypic variance was 1.8 which indicated the lower influence of environment on this parameter. Yield per square meter (g) for the checks were G14 (847.26g) which was lower than the above genotypes. The most important parameter was yield per ha (t) to select the best line, where the lines showed significant result indicating the variation of yield per ha (t). Here G01 showed maximum result and it was 9.92 t per ha followed by G13 (9.38 t per ha) and G06 (9.32 t per ha). On the other hand yield per ha (t) for the check varieties were G14 (9.5 t per ha), G15 (9.21 t per ha). So among the thirteen genotypes G01, G10 and G11 were selected as the best lines in respect of yield per ha (t) and time of maturity which could be used for further trail in future to follow the release procedure.

CONCLUSION

1. Most of the genotypes showed different traits which have excellent potentiality.

2. G01 and G11 showed higher yield/ha.

3. G11 showed early maturity than the check varieties.

4. G01, G10 and G11 were the best genotypes which could be used in the further breeding programme.

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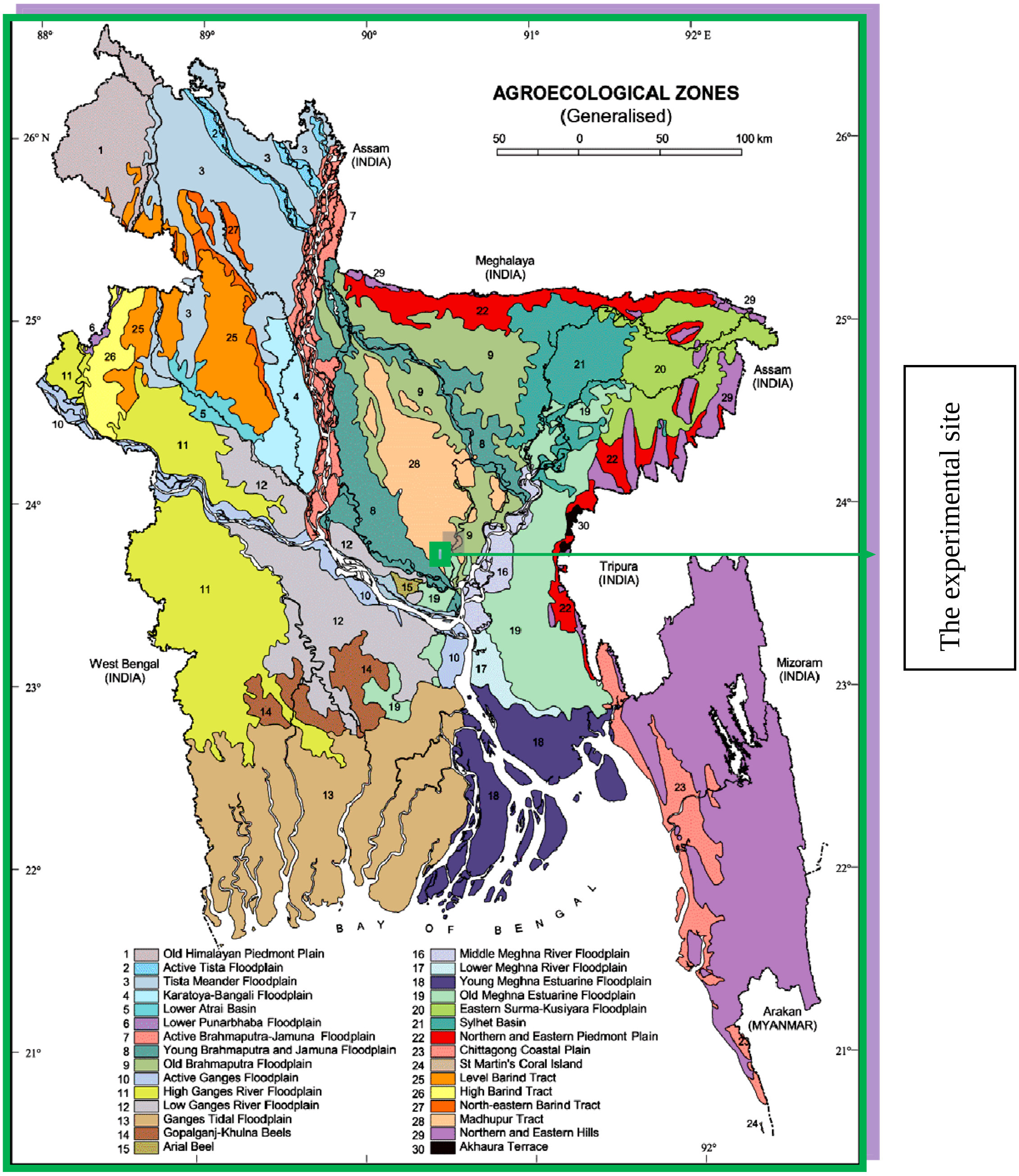
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Mean performance of various growth parameters and yield components (quantitative character) of thirteen advanced lines of boro ice

Genotypes	PH	ETP	PL	PBP	SBP	FLP	UFLP	TSW	GL	YSM	DM	YH
G01	95.74	20	25.067	13.87	55.06	211.8	13.53	26.65	8.95	964.64	144.44	9.92
G02	93.59	19.27	24.94	12.4	50.2	184.07	11.4	26.76	9.22	785.31	145.67	8.16
G03	89.11	18	24.05	13.07	48.67	205.2	13.27	24.24	8.53	888.30	145.11	8.89
G04	112.06	18.67	25.99	13.07	52.67	184.27	12.4	22.33	8.63	754.18	145.56	7.68
G05	90.47	17.13	24.57	11.47	48.53	143.4	10.53	21.67	9.34	580.22	138.22	6.15
G06	93.76	18	26.11	12.13	51.8	205.4	12.33	28.11	9.32	932.32	145.11	9.32
G07	97.86	18.33	28.25	12.47	54.4	202.27	12.53	20.93	9.38	847.43	134.44	8.47
G08	96.29	22.93	32.58	14.13	59.4	183.4	12.73	22	9.63	827.59	151.11	8.29
G09	100.07	18.2	28.32	13.13	50.27	187.33	16.47	26.76	8.81	735.72	145.78	7.37
G10	87.58	18.8	23.05	11	48.13	159.27	10.4	22.2	8.44	703.23	130.56	7.19
G11	92.22	22.06	26.29	14.67	59	207.53	13.6	26.85	9.39	777.88	133.78	7.81
G12	97.06	18.27	27.93	13.2	56.13	202.67	13.2	21.83	9.79	923.28	151	9
G13	90.92	18.33	27.54	13.33	56.53	201.27	13.67	21.83	9.33	936.03	147.22	9.38
G14	89.84	18.4	24.67	13.2	52.13	169.6	12.47	21.87	9.12	847.26	144.56	9.5
G15	96.97	19.93	23.57	11.92	48.23	197.25	14.39	27.19	9.05	939.01	140.56	9.2

PH = Plant height (cm), ETP = Effective tiller/plant, PL = Panicle length, PBP = Primary branch/panicle, SBP = Secondary branch/panicle, FLP = Filled grain/plant, UFLP = Unfilled grain/plant, TSW = Thousand Seed Weight, GL= Grain length (mm), YSM = Yield per square meter (L), DM = Days to maturity, YH = Yield/ha (t)

Appendix III. Analysis of variance of twelve important characters of rice genotypes

Source of variation	D.F.	PH	ETP	PL	PBP	SBP	FLP	UFLP	TSW	GL	YSM	DM	YH
Replication	2	7.13	0.00395	0.3257	0.06	1.3025	2.1	2.65	0.0123	0.00315	0.3	0.845	0.00070
Genotypes	14	107.06*	7.44085*	17.9098*	2.93	44.2316*	1154.53*	6.76*	20.52*	0.46346	34651.2*	112.25*	3.23249
Error	28	1.35	0.19972	0.1762	0.16	0.6822	4.22	1.89	0.0701	0.00418	1.8	0.291	0.00042

*significant at 5% level of significance

PH = Plant height (cm), ETP = Effective tiller/plant, PL = Panicle length, PBP = Primary branch/panicle, SBP = Secondary branch/panicle, FLP = Filled grain/plant, UFLP = Unfilled grain/plant, TSW = Thousand Seed Weight, GL= Grain length (mm), YSM = Yield per square meter (L), DM = Days to maturity, YH = Yield/ha (t)

Appendix IV: Heritability of twelve important characters of rice genotypes

Parameters	PH	ETP	PL	PBP	SBP	FLP	UFLP	TSW	GL	YSM	DM	YH
Heritability	96.31	92.33	97.11	85.19	95.53	98.91	46.15	98.98	93.75	99.98	99.23	99.07

PH = Plant height (cm), ETP = Effective tiller/plant, PL = Panicle length, PBP = Primary branch/panicle, SBP = Secondary branch/panicle, FLP = Filled grain/plant, UFLP = Unfilled grain/plant, TSW = Thousand Seed Weight, GL= Grain length (mm), YSM = Yield per square meter (L), DM = Days to maturity, YH = Yield/ha (t)

Appendix V. DUS tests (qualitative and quantitative characters) for various lines

Dus tests data of Genotype 01

Sl no.	Characteristics	status	code
1	Basal leaf shesth color	Green	1
2	Green color intensity of leaf blade	Dark green	7
3	Flag leaf attitude	Erect	1
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	whitish	1
8	Color of stigma	purple	1
9	Auricle color	Auricle color	1
10	Lemma and palea: anthocyanin coloration	Absent or very weak	1
11	Culm habit	Semi erect	3
12	Attitude of branches	Horizontal	9
13	Panicle exertion	Well exerted	9
14	Grain color	Straw	1
15	Color tip of lemma	red	2
16	Presence of awn	Fully awned	1
17	Distribution of awn	Tip only	1
18	Color of awns	Yellow white	1
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Very short to short	2
22	Panicle length	Medium	5
23	Culm diameter	Large	5
24	Time of heading	Very late	9
25	Effective tillers per hill	High	7
26	Thousand seed weight	High	7
27	Time of maturity	Late	7
28	Grain length	Extra long	7
29	Grain width	Medium	5
30	Yield per square meter	High	5

Dus tests data of Genotype 02

Sl no.	Characteristics	status	code
1	Basal leaf shesth color	Green	1
2	Green color intensity of leaf blade	Dark green	7
3	Flag leaf attitude	Erect	1
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	whitish	1
8	Color of stigma	purple	5
9	Auricle color	Auricle color	1
10	Lemma and palea: anthocyanin coloration	Absent or very weak	1
11	Culm habit	Semi erect	3
12	Attitude of branches	Horizontal	9
13	Panicle exertion	Well exerted	7
14	Grain color	Straw	1
15	Color tip of lemma	red	4
16	Presence of awn	Fully awned	2
17	Distribution of awn	Tip only	1
18	Color of awns	Yellow white	1
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Very short to short	2
22	Panicle length	Medium	5
23	Culm diameter	Large	5
24	Time of heading	Very late	9
25	Effective tillers per hill	High	7
26	Thousand seed weight	High	7
27	Time of maturity	Late	7
28	Grain length	Extra long	7
29	Grain width	Medium	5
30	Yield per square meter	High	5

Dus tests data of Genotype 03

Sl no.	Characteristics	status	code
1	Basal leaf shesth color	Green	1
2	Green color intensity of leaf blade	Dark green	7
3	Flag leaf attitude	Semi-erect	3
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	whitish	1
8	Color of stigma	White	1
9	Auricle color	Auricle color	1
10	Lemma and palea: anthocyanin coloration	Absent or very weak	1
11	Culm habit	Semi erect	3
12	Attitude of branches	Drooping	9
13	Panicle exertion	Well exerted	7
14	Grain color	Straw	1
15	Color tip of lemma	yellowish	2
16	Presence of awn	Absent	0
17	Distribution of awn	Tip only	1
18	Color of awns	Nil	Nil
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Very short to short	2
22	Panicle length	Medium	5
23	Culm diameter	Large	5
24	Time of heading	Very late	9
25	Effective tillers per hill	High	7
26	Thousand seed weight	High	7
27	Time of maturity	Late	7
28	Grain length	Extra long	7
29	Grain width	Medium	5
30	Yield per square meter	High	5

Dus tests data of Genotype 04

Sl no.	Characteristics	status	code
1	Basal leaf sheath color	Green	1
2	Green color intensity of leaf blade	Dark green	7
3	Flag leaf attitude	Semi-erect	3
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	whitish	1
8	Color of stigma	White	1
9	Auricle color	Auricle color	1
10	Lemma and palea: anthocyanin coloration	Absent or very weak	1
11	Culm habit	Semi erect	3
12	Attitude of branches	Drooping	9
13	Panicle exertion	Well exerted	7
14	Grain color	Straw	1
15	Color tip of lemma	yellowish	2
16	Presence of awn	Absent	0
17	Distribution of awn	Nil	Nil
18	Color of awns	Nil	Nil
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Short	3
22	Panicle length	Medium	5
23	Culm diameter	Medium	3
24	Time of heading	Very late	9
25	Effective tillers per hill	High	7
26	Thousand seed weight	Medium	5
27	Time of maturity	Late	7
28	Grain length	Extra long	7
29	Grain width	Fine	3
30	Yield per square meter	High	5

Dus tests of Genotype 05

Sl no.	Characteristics	status	code
1	Basal leaf sheath color	Green	1
2	Green color intensity of leaf blade	Dark green	7
3	Flag leaf attitude	Erect	1
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	whitish	1
8	Color of stigma	White	1
9	Auricle color	Auricle color	1
10	Lemma and palea: anthocyanin coloration	Medium	5
11	Culm habit	Erect	1
12	Attitude of branches	Horizontal	7
13	Panicle exertion	Well exerted	7
14	Grain color	Straw	1
15	Color tip of lemma	yellowish	2
16	Presence of awn	Absent	0
17	Distribution of awn	Nil	Nil
18	Color of awns	Nil	Nil
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Very short to short	2
22	Panicle length	Medium	5
23	Culm diameter	Medium	3
24	Time of heading	Late	7
25	Effective tillers per hill	High	7
26	Thousand seed weight	Medium	5
27	Time of maturity	Late	7
28	Grain length	Extra long	7
29	Grain width	Medium	5
30	Yield per square meter	Medium	3

Dus tests data of Genotype 06

Sl no.	Characteristics	status	code
1	Basal leaf sheath color	Green	1
2	Green color intensity of leaf blade	Dark green	7
3	Flag leaf attitude	Semi-erect	3
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	Yellowish green	2
8	Color of stigma	Purple	5
9	Auricle color	Yellowish green	2
10	Lemma and palea: anthocyanin coloration	Medium	5
11	Culm habit	Semi-erect	3
12	Attitude of branches	Horizontal	7
13	Panicle exertion	Well exerted	7
14	Grain color	Straw	1
15	Color tip of lemma	Red	4
16	Presence of awn	Fully awned	2
17	Distribution of awn	Tip only	1
18	Color of awns	Reddish	5
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Very short to short	2
22	Panicle length	Long	7
23	Culm diameter	Large	3
24	Time of heading	Very late	9
25	Effective tillers per hill	High	7
26	Thousand seed weight	Very high	9
27	Time of maturity	Late	7
28	Grain length	Extra long	7
29	Grain width	Medium	5
30	Yield per square meter	High	5

Dus tests data of Genotype 07

Sl no.	Characteristics	status	code
1	Basal leaf sheath color	Green	1
2	Green color intensity of leaf blade	Dark green	7
3	Flag leaf attitude	Semi-erect	3
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	Yellowish green	2
8	Color of stigma	Purple	5
9	Auricle color	whitish	1
10	Lemma and palea: anthocyanin coloration	Medium	5
11	Culm habit	Semi-erect	3
12	Attitude of branches	Horizontal	7
13	Panicle exertion	Well exerted	7
14	Grain color	Straw	1
15	Color tip of lemma	Red	4
16	Presence of awn	Fully awned	2
17	Distribution of awn	Tip only	1
18	Color of awns	Reddish	5
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Short	3
22	Panicle length	Long	7
23	Culm diameter	Large	3
24	Time of heading	Late	7
25	Effective tillers per hill	High	7
26	Thousand seed weight	Medium	5
27	Time of maturity	Late	7
28	Grain length	Extra long	7
29	Grain width	Medium	5
30	Yield per square meter	High	5

Dus tests data of Genotype 08

Sl no.	Characteristics	status	code
1	Basal leaf sheath color	Green	1
2	Green color intensity of leaf blade	Dark green	7
3	Flag leaf attitude	Erect	1
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	Whitish	1
8	Color of stigma	Whitish	1
9	Auricle color	Yellowish green	2
10	Lemma and palea: anthocyanin coloration	Medium	5
11	Culm habit	Erect	3
12	Attitude of branches	Horizontal	7
13	Panicle exertion	Well exerted	7
14	Grain color	Straw	1
15	Color tip of lemma	Yellowish	2
16	Presence of awn	Absent	0
17	Distribution of awn	Nil	Nil
18	Color of awns	Nil	Nil
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Very short to short	2
22	Panicle length	Long	7
23	Culm diameter	Medium	3
24	Time of heading	Very late	9
25	Effective tillers per hill	Medium	5
26	Thousand seed weight	Very high	9
27	Time of maturity	Very late	9
28	Grain length	Extra long	7
29	Grain width	Medium	5
30	Yield per square meter	High	5

Dus tests data of Genotype 09

Sl no.	Characteristics	status	code
1	Basal leaf sheath color	Green	1
2	Green color intensity of leaf blade	Dark green	7
3	Flag leaf attitude	Erect	1
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	Whitish	1
8	Color of stigma	White	1
9	Auricle color	Whitish	1
10	Lemma and palea: anthocyanin coloration	Medium	5
11	Culm habit	Erect	3
12	Attitude of branches	Drooping	9
13	Panicle exertion	Moderately exerted	9
14	Grain color	Straw	1
15	Color tip of lemma	Yellowish	2
16	Presence of awn	Fully awned	2
17	Distribution of awn	Tip only	1
18	Color of awns	Yellowish white	1
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Short	3
22	Panicle length	Long	7
23	Culm diameter	Medium	3
24	Time of heading	Very late	9
25	Effective tillers per hill	Medium	5
26	Thousand seed weight	High	7
27	Time of maturity	Late	7
28	Grain length	Extra long	7
29	Grain width	Medium	5
30	Yield per square meter	High	5

Dus tests data of Genotype 10

Sl no.	Characteristics	status	code
1	Basal leaf sheath color	Green	1
2	Green color intensity of leaf blade	Medium green	5
3	Flag leaf attitude	Erect	1
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	Yellowish green	2
8	Color of stigma	White	1
9	Auricle color	Yellowish green	2
10	Lemma and palea: anthocyanin coloration	Absent or very weak	1
11	Culm habit	Erect	3
12	Attitude of branches	Horizontal	7
13	Panicle exertion	Well exerted	7
14	Grain color	Straw	1
15	Color tip of lemma	Yellowish	2
16	Presence of awn	Absent	0
17	Distribution of awn	Nil	Nil
18	Color of awns	Nil	Nil
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Very short to short	2
22	Panicle length	Long	7
23	Culm diameter	Medium	3
24	Time of heading	Very late	9
25	Effective tillers per hill	Medium	5
26	Thousand seed weight	Very high	9
27	Time of maturity	Very late	9
28	Grain length	Extra long	7
29	Grain width	Medium	5
30	Yield per square meter	High	5

Dus tests data of Genotype 11

Sl no.	Characteristics	status	code
1	Basal leaf shesth color	Green	1
2	Green color intensity of leaf blade	Dark green	7
3	Flag leaf attitude	Semi-erect	3
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	whitish	1
8	Color of stigma	White	1
9	Auricle color	Auricle color	1
10	Lemma and palea: anthocyanin coloration	Absent or very weak	1
11	Culm habit	Semi erect	3
12	Attitude of branches	Drooping	9
13	Panicle exertion	Well exerted	9
14	Grain color	Straw	1
15	Color tip of lemma	yellowish	2
16	Presence of awn	Fully awned	2
17	Distribution of awn	Tip only	1
18	Color of awns	Yellow white	1
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Very short to short	2
22	Panicle length	Long	7
23	Culm diameter	Large	5
24	Time of heading	Late	7
25	Effective tillers per hill	High	7
26	Thousand seed weight	High	7
27	Time of maturity	Late	5
28	Grain length	Extra long	7
29	Grain width	Medium	7
30	Yield per square meter	High	5

Dus tests data of Genotype 12

Sl no.	Characteristics	status	code
1	Basal leaf shesth color	Green	1
2	Green color intensity of leaf blade	Medium green	5
3	Flag leaf attitude	Erect	1
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	whitish	1
8	Color of stigma	White	1
9	Auricle color	Auricle color	1
10	Lemma and palea: anthocyanin coloration	Absent or very weak	1
11	Culm habit	Erect	1
12	Attitude of branches	Drooping	9
13	Panicle exertion	Well exerted	9
14	Grain color	Straw	1
15	Color tip of lemma	yellowish	2
16	Presence of awn	Absent	0
17	Distribution of awn	Nil	Nil
18	Color of awns	Nil	Nil
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Very short to short	2
22	Panicle length	Long	7
23	Culm diameter	Large	5
24	Time of heading	Very late	9
25	Effective tillers per hill	High	7
26	Thousand seed weight	High	7
27	Time of maturity	Very late	9
28	Grain length	Extra long	7
29	Grain width	Medium	7
30	Yield per square meter	High	5

Dus tests data of Genotype 13

Sl no.	Characteristics	status	code
1	Basal leaf shesth color	Green	1
2	Green color intensity of leaf blade	Medium green	5
3	Flag leaf attitude	Erect	1
4	Leaf blade pubescent	Pubescent	3
5	Leaf ligule	Present	9
6	Ligule shape	2-cleft	7
7	Ligule color	whitish	1
8	Color of stigma	White	1
9	Auricle color	Auricle color	1
10	Lemma and palea: anthocyanin coloration	Absent or very weak	1
11	Culm habit	Erect	1
12	Attitude of branches	Drooping	9
13	Panicle exertion	Well exerted	9
14	Grain color	Straw	1
15	Color tip of lemma	yellowish	2
16	Presence of awn	Absent	0
17	Distribution of awn	Nil	Nil
18	Color of awns	Nil	Nil
19	Leaf senescence	Intermediate	5
20	Caryopsis scent	Non scented	0
21	Culm length	Very short to short	2
22	Panicle length	Long	7
23	Culm diameter	Large	5
24	Time of heading	Very late	9
25	Effective tillers per hill	High	7
26	Thousand seed weight	High	7
27	Time of maturity	Very late	9
28	Grain length	Extra long	7
29	Grain width	Medium	7
30	Yield per square meter	High	5

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

A. Morphological characteristics of the experiment field

Morphological features	**Characteristics**
Location	Sher-e-bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General soil type	Deep red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical composition of the soil

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

Source: Central Library, Sher-e-Bangla Agricultural University

C. 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)	816.00	Hunter, 1984
9	Ph (1 : 2.5 soil to water)	95.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Source: Central Library, Sher-e-Bangla Agricultural University

Appendix VI. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from October, 2018 to April, 2019

Month	Air temperature (˚C)		Relative humidity (%)	Total Rainfall (mm)	Sunshine (hr.)
October, 2018	32.6	23.8	172.3	172.3	5.2
November, 2018	29.6	19.2	34.4	34.4	5.7
December, 2018	26.4	14.1	12.8	12.8	5.5
January, 2019	25.4	12.7	7.7	7.7	5.6
February, 2019	28.1	15.5	28.9	28.9	5.5
March, 2019	32.5	20.4	65.8	65.8	5.2
April, 2019	33.7	23.6	165.3	165.3	5.9

Source: Sher-e-Bangla Agricultural University Weather Station